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Intraoperative Neuromonitoring (IONM) and Hospital Outcome Metrics for Lower Risk Spinal Procedures: A Retrospective Analysis of Length of Stay and 30-day Readmission Rates for High and Low Users of IONM

Derek S. Connor
Medical University of South Carolina

Intraoperative Neuromonitoring (IONM) and Hospital Outcome Metrics for Lower Risk Spinal Procedures: A Retrospective Analysis of Length of Stay and 30-day Readmission Rates for High and Low Users of IONM.

BY

Derek S. Connor

A doctoral project submitted to the faculty of the Medical University of South Carolina in partial fulfillment of the requirements for the degree Doctor of Health Administration in the College of Health Professions.

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Approved by:

Chair, Project Committee	Kit Simpson, DrPH	5/1/17 Date
Member, Project Committee	Scott Davis, PhD	4/26/17 Date
Member, Project Committee	Bryan Wilent, PhD, DABNM	4/25/2017 Date
Dean, College of Health Professions	James S. Zoller, PhD	6/5/17 Date

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Chairperson: Kit Simpson, DrPH, Professor, Medical University of South Carolina

Committee: Scott Davis, PhD, Associate Professor, Tulane and Louisiana State Universities
Bryan Wilent, PhD, DABNM, Vice President of Quality and Clinical Performance, SpecialtyCare

Objective: To explore the relationship between the utilization rates of Intraoperative Neuromonitoring (IONM) across hospitals, and the impact on surgical outcomes of 30-day readmission (30DRR) and length of stay (LoS) for lower risk, non-complex spinal procedures. The following questions will be addressed: 1) Will hospitals with a high rate (> 67th percentile) of IONM use for low risk spinal surgeries have lower LoS than hospitals with low use (< 33rd percentile) of IONM?; 2) Will hospitals with a high rate (> 67th percentile) of IONM use for low risk spinal surgeries have lower 30DRR than hospitals with low use (< 33rd percentile) of IONM?; 3) High surgical volume hospitals with high IONM use rate (>67th) during low risk will have lower 30-day readmission rates than similar high volume hospitals with low IONM use; and, 4) Will high surgical volume hospitals with high IONM use rate (>67th) during low risk will have lower 30-day readmission rates than similar high volume hospitals with low IONM use?

Methods: A retrospective analysis of multi-state hospital billing data was conducted utilizing the 2012 Agency for Healthcare Quality and Research (AHRQ), Healthcare Cost and Utilization Project (HCUP) Statewide Inpatient Databases (SID) for Florida, Massachusetts, New York, and Washington. Multivariable and gamma distributed, generalized linear log linked, regression models were used to test the association between hospital IONM utilization and hospital outcomes of 30DRR and LoS, respectively.

Results: Hospitals in the top thirtile of IONM utilization had a 14.9% lower chance (OR of .851, *p* value .001) of a 30-day readmission and no significant difference in LoS, when compared to the bottom thirtile of IONM hospitals users, for surgeries within the Diagnostic Related Groups (DRGs) of 460 and 473. Hospitals in the subgroup of top 50th percentile of hospitals in the state by surgical volume had 8.3% lower chance (OR of .917, *p* value .023) of 30-day readmission when compared to the subgroup of bottom 50th percentile of all surgeries, and a small difference in mean LoS, 0.3 days (95% CI 3.04-3.09, 2.74-2.78).

Discussion: Comparing the top thirtile of IONM utilizing hospitals to the bottom third of utilization hospitals reduced the chances of 30-day readmission by 14.9% for less complex and lower risk spinal procedures (DRGs 460 and 473). Additionally, this 14.9% lower chance of a 30-day readmission were further supported by the findings that surgical volume made no significant difference in this result. The top 50th percentile subgroup of all hospital spine surgeries was analyzed and yielded an 8.3% lower

chance of incurring a 30-day readmission when compared to the bottom 50th percentile subgroup. Ultimately, the significant difference in 30DRR for the top thirtile of hospital IONM utilizers should not be attributed to organizational surgical volume alone, thus further supporting IONM's influence in reducing 30DRR.

Additional research is warranted to further assess the association between IONM and LoS. In general, adjusted estimations of mean LoS did not yield any differences for high or low IONM utilizing hospitals across lower risk, less complex procedures. For the top and bottom 50th percentile subgroups, there was a moderate increase in LoS for the top 50th percentile (0.3days) Further exploration of IONM's utility iis warranted, and ideally these analyses will be based on prospective, longitudinal datasets and registries with more detailed documentation. This expanded information would allow for more analytical and clinical control for the largely unstandardized practice of IONM.

Keywords: Intraoperative Neuromonitoring, IONM, IOM, length of stay, LoS, 30-day readmissions, spine surgery, utilization, hospital outcomes

CHAPTER 1
INTRODUCTION

Background

Over the last two decades the frequency of spine surgeries has dramatically increased as American healthcare providers conducted upwards of 3.6 million spinal fusions (Goz et al., 2015). Any surgery undoubtedly carries risk to a patient's safety and spinal surgery is no different. Hamilton et al. (2011) analyzed a retrospective database containing 108,419 spinal surgeries and found 0.95 percent of these patients developed a new neurologic deficit (NND). While this incidence of NND seems low, the consequences of experiencing a NND after spine surgery are the most feared complications by the care team and the patient. These injuries can range from isolated sensory and motor deficits to paraplegia, quadriplegia, or even death. The quality of life impact to a patient from a NND is a dramatic event that can be life-long. A NND is a tragic outcome and has obvious lasting emotional consequences for caregivers but can also manifest in medical-legal concerns, degraded public perception, loss of future business, loss of accreditation, and fiscal penalties for hospitals.

To reduce the likelihood of a NND and thus the consequences for the patient, medical providers and hospitals can utilize Intraoperative Neuromonitoring (IONM) on various orthopedic and neurological related surgeries. IONM provides risk reduction by communicating real-time, functional, electro-neurodiagnostic information collected directly from the patient. This intraoperative neurological data includes but is not limited to: sensory and motor function of the spinal cord and brain, spinal nerve root activity, and blood perfusion to critical neuronal structures and pathways (Møller, 2011). The surgical team is then able to act upon this information to deliver interventions to reduce any potential complication. These interventions can range from readjusting spinal pedicle screws, derotating spinal rods, adjusting the patient's positioning on the surgical table or even adjusting the patient's blood pressure through anesthetic control. Through these interventions, IONM assists physicians and hospitals conduct safer spinal surgery, reducing intraoperative complications leading to less post-operative deficits (Cole, Veeravagu, Zhang, Li, & Ratliff, 2014; Fehlings, Brodke, Norvell, & Dettori, 2010; Husain, 2015; Ney, van der Goes, & Nuwer, 2015).

The tenants of IONM did not start with protecting patients undergoing spine surgery in operatory setting. The foundations of current day IONM find way their back to as far as the early 1940s for patients suffering from seizure disorders. Drs. W. Penfield and H. Steelman were the first to publish results treating focal epilepsy by using electroencephalography (EEG) to localize seizure activity in a patient's brain (Penfield & Steelman, 1947). In those same years, the first description of somatosensory evoked potentials (SEPs), widely used today in most IONM procedures, is described and analyzed by George Dawson in 1947 as a means to test a patient's sensory pathway functioning (Hauck, 2015). Fast forward a few decades to the 1960s, before the expansion of spinal surgery, and you will see IOM as a small niche service, providing auditory brainstem responses (ABRs) and electromyography, to protect a patient's post-operative hearing and facial function after undergoing brain tumor resections (Møller, 2011). Following shortly thereafter, the IONM industry begins to truly establish itself through the use of somatosensory evoked potentials (SEPs) to monitor the functional integrity of spinal cords during Harrington rod instrumentation for scoliosis corrections (Zouridakis & Papanicolaou, 2001).

The original idea of SEPs protecting the thoracic cord during scoliosis corrections remains valid today (Glover & Carling, 2014). However, IONM has now evolved into multi-modality monitoring, offering protection of both the sensory and motor tracts of the spinal cord and certain brain structures. This has influenced IONM professionals monitoring procedures across a multitude of surgical disciplines: brain surgery, adult spine surgery, pediatric deformities, vascular surgeries, and even otolaryngology (Lall et al., 2012). IONM consists of three primary functions: the surgical neurophysiologist located inside the operating room responsible for the technical data gathering (technical component), the interpreting physician who interprets the data to make medical interventions (professional component), and the physical machinery and equipment connected to the patient. The risk reduction afforded through the combination of highly skilled surgical neurophysiologists and physicians creates an attractive yet expensive service for surgeons and hospital administrators. The IONM team utilizes electrophysiological, differential amplifiers to collect their data, and this data can be transmitted to the appropriately credentialed physicians via tele-medical infrastructure. The combination of these three functions above create the IONM team who have shown to reduce surgical risk, decrease post-operative complications, and decrease the economic impact of care of high risk spine surgery (Ney et al., 2015; Ney, van der Goes, & Watanabe, 2013; Nuwer et al., 2012).

To no surprise, surgeons and hospitals are attracted to IONM's value proposition. IONM brings their surgical service lines reduced risk and less complications. Today, IONM continues to aggressively proliferate, in lock-step with spinal surgery, across the surgical service landscape of the American healthcare system. Year to year, IONM continues to sustain and display significant room for future growth with only approximately 12 percent of spinal procedures using IONM (James, Rughani, & Dumont, 2014). IONM can be indicated in any spine surgery, or even any surgery that puts a vascular structure of the spinal cord at risk to include: spinal laminectomies, discectomies, fusions, corpectomies, and tumor resections. With any of these surgical procedures, invasive or minimally invasive, there is real risk for patient injury.

Concurrently with the increase of spine surgeries and utilization of IONM, is the exponential increase in the cost of spine surgeries. Alosh, Li, Riley, and Skolasky (2015) concluded the average hospital's charges for spine surgery continue to increase yearly, and they demonstrate charges almost doubling from 2000 to 2009. There are a multitude of possible factors contributing to this explosion of spine surgery cost: aging population, surgical patients presenting with more comorbidities, more post-operative complications, external insurance and hospital reimbursement strategies. Yet, Ney and van der Goes (2012) quantified that each post-operative neurological complication can cost upwards of $63,387 in additional patient charges. In the event of an injury, this is an undeniable increase to the total cost of spine surgery. The combination of ever increasing costs, patient comorbidities and the dramatic consequences to post-operative spinal complications amplifies the need for services such as IONM to increase positive outcomes and stabilize inflating costs. Attempting to avoid preventable, life-long injuries is a mission all healthcare providers can and should support. IONM has been shown to do just this across a multitude of studies (Cole et al., 2014; S. F. Davis, Corenman, Strauch, & Connor, 2013; Fehlings et al., 2010; Fisher, Raudzens, & Nunemacher, 1995). However, physicians and hospital administrators must ensure the services they are purchasing are living up to the value statement the IONM industry claims to deliver.

IONM providers continue to aggressively market their services to physicians, hospital leadership and insurance companies. As a majority of IONM practices are a down-stream contracted service to hospitals, they have various external customers to demonstrate their value to. IONM generates its revenue through billing third party payers, hospitals, and patients. With this multi-layered billing structure, the IONM industry and all its customers are better served through additional and diversified empirical support for these services. The gold standard for empirical support in clinical services is randomized clinical trials (Guyatt, Rennie, Meade, Cook, & American Medical Association., 2015). There is significant debate surrounding the ethics of conducting randomized clinical trials (RCTs) with IONM at this current point in IONM's life cycle (Eccher, 2014; Howick, Cohen, McCulloch, Thompson, & Skinner, 2016). However, the same authors discovered that the surgical interventions have received less pressures to substantiate their techniques through the use of RCTs. The other complication with prospective RCTs is the sheer number of cases required to appropriately assess the extremely small complication rates with spinal surgery while using IONM (Hamilton et al., 2011). To complicate the matters further, there is still significant disagreement on the actual correct reporting procedures for spinal surgeries, especially from the majority of retrospective analyses contained in the literature Nasser et al. (2010).

Despite these complicating factors, the pursuit of empirical due diligence is still a worthwhile effort, especially for an industry such as IONM incurring significant growth and costs (James et al., 2014). Hospital leadership must ensure the support services they partner with contributes to the myriad of safety and fiscal metrics they are judged against. IONM defends its services to this diverse customer base through the value proposition of reducing the risk of iatrogenic injury during spine and cranial surgeries where a patient's major neuronal and vascular structures are manipulated (Howick et al., 2016). There is significant research suggesting IONM can be predictive of NNDs and reduce post-operative complications in high risk procedures such as pediatric and adult deformity correction procedures, myelopathic patients, and tumor resections (Ney et al., 2013; Sala & Di Rocco, 2015). While researchers such as Ney et al. (2015) confirm that spine surgery contains real risk of neural injury, the costs and frequency of spine decompressions and fusions continue to grow at an alarming rate. Conflicting viewpoints about risk versus cost begin when IONM is utilized for lower risk procedures. Multiple studies state that they advocate for limiting IONM's use to only high risk procedures such as pediatric deformities, intramedullary spinal cord tumors, or myelopathic patients spanning multiple levels of the spinal column (Hawksworth, Andrade, Son, Bartanusz, & Jimenez, 2015; Vadivelu et al., 2014). The remaining lower risk procedures include multi-level, lumbar and cervical decompressions and fusions on patients who do not present as myelopathic. The literature supporting IONM's use on these lower risk procedures remains largely unaddressed and conflicted (Cole et al., 2014; Garces, Berry, Valle-Giler, & Sulaiman, 2014). There remains a significant level of work to build the appropriate levels of trust and value regarding IONM with real world evidence on these specific procedures for both surgeons and hospitals.

There is not only a gap in the literature when it comes to the utility of IONM on lower risk procedures and their related outcomes, but there are also substantial vacuums of information on how IOM contributes to meaningful hospital performance metrics. To complete the picture of IONM's overall effectiveness and contribution to patient safety and outcomes, further analysis is required to assess IONM on lower risk procedures from the medical facility standpoint. The frequency of injuries in various spinal surgeries must be weighed against the larger landscape of medical decision making and hospital performance such as overall cost, influence on hospital 30DRR and LoS. 30DRR have received a large amount of attention from the Centers of Medicare and Medicaid (CMS) as a metric to significantly improve. CMS and their associates stated that in 2008, 20 percent of all Medicare recipients were readmitted to the hospital within 30 days, costing upwards of $17.4 billion dollars in additional healthcare resources (Bernatz & Anderson, 2015). LoS is also a quality indicator growing in popularity requiring further analysis. IONM's influence on the total time a patient spends in the hospital remains largely underreported from a hospital's context, and additional research is required to substantiate any influence of IONM on LoS for spinal patients undergoing low risk procedures. The majority of the studies assessing IONM's relationship to lower risk spinal surgeries focus at the patient level of clinical outcomes and costs. However, a widening gap of knowledge exists with IONM's use on lower risk spinal procedures and the related impacts to the collective hospital outcomes on LoS and 30DRR. Both of these metrics have widely become a proxy for hospital quality metrics across the healthcare landscape (McCarthy et al., 2014; Missios & Bekelis, 2016b).

Problem Statement

Even though spinal surgery has come under considerable scrutiny over the last several years, there is no denying the current increase in utilization rates. Goz et al (2015) highlight 500+ spinal surgeries occurring every day in the United States, and this is roughly twice as much as our developed partners in Canada, Norway, and Finland. Unfortunately, in the face of increased utilization, the American healthcare system displays an inability to contain the costs of spinal procedures (Deyo & Mirza, 2009; Missios & Bekelis, 2015) Goz et al. (2015) highlight the same spinal procedure, anterior cervical discectomy and fusion (ACDF), can range from $10,879 to $29,929 in total costs. Factors driving up the cost of spine surgery are numerous, but neurological injuries have the highest potential for increased surgical and life-time costs for the patient and longer term consequences for hospitals (Hamilton et al., 2011; Ney et al., 2015; Ney et al., 2013).

For a large cross section of these spinal surgery patients, IONM can be indicated for use by the surgeon or by hospital policies. Hospital and surgical practices greatly benefit when they can defend their service line operations to regulators, payers, and their medical staff (White, 2016). IONM has been shown to be highly predictive of potential intraoperative complications, and also to reduce neurological injuries in high risk spinal surgery across a multitude of procedures (Fehlings et al., 2010; Nuwer et al., 2012; Sala & Di Rocco, 2015). On the other hand, it remains to be seen if this positive predictive value (PPV) of IONM translates into meaningful impact for hospitals serving the wider heterogeneous mix of patients undergoing the various spinal procedures. From the hospital’s perspective, it is vital to ensure their continuum of patient care performance remains competitive when benchmarked against national standards and competitors (Bernatz & Anderson, 2015; Khanna et al., 2015). Ever increasing in popularity are a hospital's performance on 30DRR and LoS. With spine surgeries being one of the most frequently used surgical techniques across the United States, there are significant opportunities to ensure IONM contributes to a hospital's overall performance in a meaningful way. As IONM continues to grow across hospital service lines, facility administrators would benefit from understanding the true impact of IONM on the popular benchmarks of performance: 30DRR and LoS.

IONM is performed to protect patients from neurological damage during high risk spinal procedures. A broad base of literature supports the claim IOM assists in reducing surgical complications in high risk procedures and thus may lead to a reduced LoS, lower 30DRR, and decreased overall cost of care. Although the current body of literature is inconsistent on IONM as an effective use of resources on lower risk procedures. The current reimbursement environment suggests payers are not supporting the larger claims for lower risk surgeries utilizing IOM (Ney, 2013). Additionally, there is an absence of research assisting hospital and surgical practice administrators on the usefulness of IONM across lower risk procedures for their facilities, and they would benefit to develop further policy surrounding IONM's use. Understanding the clinical, financial, and performance based impact of IONM, from multiple perspectives, will assist in developing long-term, sustainable service protocols to help reduce negative outcomes and increase hospital performance. This study was designed to assist healthcare and clinical leadership better understand where IONM influences LoS and 30DRR across lower risk spinal procedures, and to also examine the potential contribution of a facility's volume of low-risk procedures.

Objective

The study objective is to compare the use of IONM in lower risk spinal procedures to identify any association between rate of hospital use oh IOM and mean the LoS and 30DRR. We pose the following hypotheses:

Hypothesis 1: Hospitals with a high rate (> 67th percentile) of IONM use will have lower mean length of stay (LoS) than hospitals with low use (< 33rd percentile) of IONM.

.Rationale: Availability of and regular use of IONM in an institution may be expected to increase the likelihood of IONM use for all patients that may benefit, this would be expected to reduce the number of adverse surgical events that occur, with an overall effect of improving mean LOS for the population.

Hypothesis 2*:* Hospital with high rate (> 67th percentile) of IONM use will have lower 30-day readmission rates than hospitals with low use (< 33rd percentile) of IONM.

Rationale: IONM reduces adverse surgical events that require readmission for correction.

Hypothesis *3:* High surgical volume hospitals with a high IONM use rate (>67th percentile) of IONM will have shorter mean LoS when compared to high surgical volume hospital with low rate of IONM use.

Rationale: Organizational practice patterns that routinely include use of IONM for low risk spinal surgery leads to better integration of this technology into surgical routines, increases team experience and leads to fewer adverse surgical effects, lower LOS and decreased population risk of readmissions.

Hypothesis H_4. High surgical volume hospitals with high IONM use rate (>67th) during low risk will have lower 30-day readmission rates than similar high volume hospitals with low IONM use.

Rational: Medical facilities who demonstrate high volumes of spinal surgeries have documented better surgical outcomes. Comparing facilities with high volume of lower risk spinal surgery who utilize IONM against facilities who also have high rates of lower risk spine surgery but who do not utilize IONM, will show the benefit of IONM separate from the effect of surgery volume.

Population

Lower risk spinal procedures are surgeries performed to treat degenerative injuries to a patient's central nervous system and/or spinal column. These procedures involve removing human bone and soft tissue in the lumbar and cervical spinal column and replacing them with metal, plastic, and/or biogenic implants. These techniques decompress central nervous system structures, stabilize boney structures, and aid in increasing function and/or reducing pain (Deyo, Nachemson, & Mirza, 2004). This study population is limited to these types of procedures which include lumbar and cervical decompressions involving three or less vertebral levels for patients who are not myelopathic. All data for this study is derived from the Healthcare Cost and Utilization Project (HCUP) State Inpatient Data (SID) databases. provided by the Agency for Health Research and Quality (AHRQ). The HCUP SID databases include discharge records from community hospitals across the respective participating states. The SID datasets capture all patients, regardless of third party payer, and together encompass approximately 97 percent of all U.S. community hospital discharges.

CHAPTER II
REVIEW OF THE LITERATURE

Available literature was reviewed across a variety of areas related to the current research questions to further develop the background and need for this study. The literature review analyzed previous studies, their designs, and relevant recommendations for future research. The primary goal of the literature review was to synthesize the relevant information surrounding intraoperative neuromonitoring's (IONM) use on lower risk spinal procedures, and IONM's influence on respective hospital performance outcomes of patient LoS and 30DRR, across hospitals with various IONM utilization. This review addresses the current lack of literature supporting IONM's use on lower risk procedures, and to also illuminate the lack of research on IONM, and any contributing factors, as a useful service from a hospital's perspective.

Methods

The literature review began utilizing a variety of search terms through the OVID MEDLINE database. The key search words are encompassed across the following areas related to the research questions: spinal surgery, low risk spinal surgery, high risk spinal surgery, spinal surgery complications, spinal surgery deficits, intraoperative neuromonitoring, intraoperative neurophysiological monitoring, neuromonitoring, IOM, IONM, length of stay, LoS, 30DRR, intraoperative neuromonitoring value, intraoperative neuromonitoring evidence based medicine, hospital volume, and hospital IONM volume. The articles generated form this collective query were screened at the abstract level, and the relevant literature was subsequently electronically downloaded from OVID MEDLINE.

As the articles were populated and analyzed from the initial set of search terms, a trend of authors became readily apparent as the primarily contributors to the research questions. Further OVID MEDLINE searchers were conducted on the following others to ensure all relevant articles were retrieved: John P. Ney, Marc Nuwer, David N. van der Goes, Jonathan Watanabe, Justin Smith, Richard Deyo, and Francesco Sala. Lastly, specific journals were searched via OVID MEDLINE for articles related to the research questions and relevant authors: *Annals of Surgery, Journal of the American Medical Association, European Spine Journal, Journal of the American College of Surgery, New England Journal of Medicine, The Spine Journal, Journal of Clinical Neurophysiology, Journal of Neurosurgical Spine, Journal of Neurology, Neurosurgery Focus,* and *World Neurosurgery*. All electronic full-text articles were downloaded from the respective journal's website, and organized into a software based citation manager, EndNote v7.5.3.

All searchers were conducted from August 2016 to December 2016. The combination of these search methods yielded 107 articles relevant to the research questions. Remaining pertinent information was acquired from websites administered by governmental professional organizations such as: Centers of Medicare and Medicaid (CMS), The Leapfrog Group, Agency for Healthcare Research and Quality (AHRQ), American Hospital Association (AHA), American Society of Neuromonitoring (ASNM), the American Society of Electrodiagnostic Technologists (ASET), American Clinical Neurophysiology Society (ACNS), Medical University of South Carolina (MUSC) Comparative Effectiveness and Data Analytics Research Resource (CEDAR), and the American Board of Registered Encephalographic Technologies (ABRET).

Economic Impact of Spinal Surgery Growth

The United States spends more on healthcare than any other western, developed nation, reaching $3.2 trillion dollars, or 17.5 percent of America's gross domestic product in 2015 (Hellander, 2015; Thorpe, 2006). With a predicted growth rate of 5.8 percent a year, America's healthcare system will achieve an unprecedented 19.6 percent of the nation's GDP by 2024 (Keehan et al., 2015). Even in the face of these staggering projections, there is significant concern the U.S. healthcare system is still embracing unsustainable practices. One of the medical practices included in suspicion of unsustainability surrounds the larger enterprise of spinal care. Back pain, specifically lower back pain, is one of the oldest studied conditions and remains the highest ranked disability across the world today, and it is expected to continue to grow in prevalence as our population aggressively displays patient demographics with higher age and higher frequency of comorbidities (Hoy et al., 2014; Tarpada, Morris, & Burton, 2017). A large component of America's healthcare expenditures is spent addressing this global epidemic of back pain in the form of various spinal treatments and surgeries. Spinal surgeries comprise one of the highest frequently used procedures in the nation, and they consistently yield the highest year-to-year increase in total costs for hospitals, reaching an aggregate of $11.218 billion in 2011. (Akins et al., 2015; Cutler & Ghosh, 2012; Elixhauser & Andrews, 2010; Ney et al., 2015).

With significant debate still ongoing on the appropriate indications for spine surgery, these procedures continue to grow at a rapid rate, increasing 77 percent from 1996 to 2001, far outpacing other orthopedic procedures by six fold (Deyo & Mirza, 2009; Deyo et al., 2004). The combination of continued concerns surrounding the appropriate indications for spine surgery, and the healthcare system's inability to control the economic impact of spinal treatments, creates significant variance in the economic justifications spinal surgery (Alosh et al., 2015; Ugiliweneza et al., 2014). M. A. Davis, Onega, Weeks, and Lurie (2012) discovered between 1999 and 2008, the combined global cost of surgery, therapy, and primary care for patients being treated for lumbar and cervical conditions increased by 95 percent. These findings were further supported by both Goz et al. (2015) and Cole et al. (2014), demonstrating wide spectrums of cost for surgical treatment of lower risk spinal procedures occurring across the country. These authors demonstrate these lower risk spinal procedures and their widely variable costs to insurance companies as:

1. Anterior Cervical Discectomies and Fusion (ACDF) ranged from $10,879 to $24,923;
2. Posterior Lumbar Interbody Fusion (PLIF) ranged from $19,989 to $37,426;
3. Lumbar Laminectomy ranged from $8,144 to $15,905.

A large retrospective analysis yielded a mean and median hospitalization cost for patients undergoing the family of spinal surgery as $21,298, with a 95% confidence interval of $21,868-$21,988, and $14,202 (Missios & Bekelis, 2015).

There are additional variables influencing such a wide range in costs for spinal procedures. Over the years there has been a significant technological surge in new techniques and procedures allowing surgeons to treat patient populations they wouldn't have been able to treat before (Thorpe, 2006). Also, the larger landscape of patient demographics continues to shift to individuals living longer than they did before. This longer life expectancy unfortunately carries with it the natural tendency for patients to present with more comorbidities to include heart disease, obesity, pulmonary disorders, and diabetes, all contributing factors to spinal surgery costs and risks (Deyo et al., 2010). A surgeon's preference of types of procedures, approach, and what support services to utilize on their spine surgeries are also large determinants of cost (Kazberouk, Sagy, Novack, & McGuire, 2016; McLaughlin, Upadhyaya, Buxey, & Martin, 2014). On top of the preoperative factors that drive up spinal procedure expenditures, there are also intraoperative and post-operative factors contributing to the ballooning the economic impact of spinal procedures. Intraoperative variables would include any type of surgical events to include complications, delays, cancellations, and the type of surgical technique and indicated medical instrumentation. Post-operative complications capture preoperative and intraoperative events that manifest themselves in the form of infections, neurological complications, musculoskeletal pain, and even possibly readmission back to the facility for revision surgery. There are also several considerations driving the cost of spinal surgery and these include: the type of medical facility, in-patient vs out-patient status, teaching status, ambulatory surgery center vs hospital setting. All of these variables have a significant role in the overall cost of spine surgery (McGirt, Godil, Asher, Parker, & Devin, 2015). However, Dimick et al. (2004) established that post-operative surgical complications make up a significant area of economic risk and costs for hospitals and third party payers. For the betterment of our institutions and patients, this risk must be further explored.

Defining the Risks of Spinal Surgery

It always in the best interests of the patients and surgeons to truly understand the potential complications of spine surgery. This is one of the most important tenants of patient’s informed consent for surgery (Saigal et al., 2015). Yet, clearly defining the complication of risk in spine surgery is no simple task, and this barrier to transparently codifying surgical risk is paramount to creating sustainable, quality improvements in health services (Dimick et al., 2004; Hamilton et al., 2011). The risk of spine surgery and negative outcomes begins with the patient. The literature shows a wide degree of patient factors possibly influencing poorer spinal surgery outcomes, numbering upwards of twenty primary factors. However, the primary factors associated with higher spinal surgery complications include: high body mass index (BMI), older age, sex, geographical location, pre-operative diagnosis, presenting multiple comorbidities, and the patient’s American Society of Anesthesiologists (ASA) physical status classification (Akins et al., 2015; Deyo et al., 2010; Mehrotra & Dimick, 2015; Wang et al., 2012).

This family of spinal procedures inherently continues carry more risk compared to other classes of surgery even when controlling for the widely variable set of factors behind spine surgery. Examples of these procedures include both intra and extradural spinal cord tumor removals, and cauda equina untethering. All of these procedures involve greater degrees of neural and vascular manipulation by the surgeon. The literature considers these procedures higher risk compared to others with a morbidity ranging from 3.7% to 7.5% (Forster, Marquardt, Seifert, & Szelenyi, 2012).

Then there are procedures such as lumbar laminectomies where small pieces of bone from the posterior spinal column are removed. These procedures are considered much lower risk compared to spinal tumor removals, only carrying a risk of morbidity between 0.0% to 1.18% (Cole et al., 2014). Laminectomies are procedures where only small fragments of bone are removed with barely any manipulation of the patient’s nervous system. Within the spectrum between these two given examples of spine surgery, there is a heterogeneous span of procedures with varying degrees of risk. The risk of spinal procedures can be based on the patient requiring hardware implantation in the form of metal pedicle screws placed into the vertebral column, interbody spacers inserted inside the vertebral disc space, or even metal rods spanning the entire cervical, thoracic, and lumbar. Procedural risk also varies dependent upon the specific region of the spinal cord and also if the procedure involves more spinal levels (Worley et al., 2016). Procedures covering a significant portion of the cervical spine involve more critical pathways that control essential life functions such as breathing and motor and sensory capabilities of both the arms and legs. In contrast, lower lumbar spine surgeries can functionally impact lower limb functioning along with bowel and bladder control.

Succinctly calculating all the variables that feed into the overall risk for a patient undergoing spinal surgery is extensive. This equation requires assessment of both the patient's history, preoperative condition, and the type and location of surgery. Illuminating the majority of these factors assists clinicians and administrators to better understand the risk pool their patient population compromises. Following the combined foundations outlined in the recent literature, the lower risk spine surgeries can be defined as procedures displaying the majority of the following factors (Basques, Bohl, Golinvaux, Smith, & Grauer, 2015; Deyo et al., 2010; Kimmell et al., 2015; Wang et al., 2012; Yadla et al., 2015):

1. Patient Factors:
    a. Younger patients (<60 years old)
    b. No previous spinal surgery

c. ASA classification less than three
d. Non-myelopathic and non-trauma preoperative diagnosis
e. Overall, presenting with less than three comorbidities
f. No significant cardiovascular or pulmonary medical history

2. Procedural Factors:

    a. Conducted in an out-patient setting vs inpatient setting
    b. Simple spinal fusions:
        i. involving a singular approach: anterior, posterior, or lateral
        ii. Spinal fusions involving only one or two intervertebral disks

    c. Simple decompressions;

        i. Involving a singular approach: anterior, posterior, or lateral
        ii. Involving any combination of a discectomy or laminectomy (without fusion)

Post-Operative Complications in Lower Risk Spinal Surgery

Complications are an assorted collection of unanticipated surgical events. They can manifest into a negative, post-operative outcomes for a patient. These resulting complications present as but are not limited to: wound infections, wound hematomas, neurological deficits, cardiovascular issues, respiratory difficulties, thromboembolic injuries, psychological changes, sepsis, dysphasia or even death (Hamilton et al., 2011; McCormack et al., 2012; Schoenfeld, Ochoa, Bader, & Belmont, 2011). The majority of the spinal surgery literature assesses post-operative complications through retrospective analysis of administrative and insurance claims datasets. Nasser et al. (2010) and Wang et al. (2012) both discovered this retrospective technique can attribute to underreporting of overall complication rates. Keeping this concern in the forefront, as a general overview, the largest studies to date suggest varying degrees of complications rates across for spinal surgeries:

1. Average Mortality Rate of 0.18 percent (Smith et al., 2012);

2. Average Overall Complication Rate of 16.4 percent (Nasser et al., 2010)
3. Average new neurological deficit of 1.0 percent (Hamilton et al., 2011);
4. Average wound infection, superficial and deep, of 1.1 percent (Smith et al., 2010).

Further analysis of the most common, lower risk spinal procedures, with their respective overall complication rates, yields they can range from (Kimmell et al., 2015; Medvedev, Wang, Cyriac, Amdur, & O'Brien, 2016; Mehrotra & Dimick, 2015; Smith et al., 2010; Smith et al., 2012):

1. Lumbar Discectomy (LD) – 1.03-3.6 percent;
2. Simple (2 levels or less) Lumbar Fusion – 0.98 percent;
3. Simple Anterior Cervical Discectomy and Fusion (ACDF) – 0.9-2.4 percent;
4. Lumbar Stenosis Decompression – 0.95-7.0 percent;
5. Posterior Cervical Fusion – 36.1 percent.

Strictly assessing lower risk procedures, the consequences of complications can still be quite severe and real. Based on corresponding complication rates for these procedures above, they can further vary based on patient population and surgical technique used (Akins et al., 2015; Mehrotra & Dimick, 2015; Smith et al., 2010; Wang et al., 2012). The same type of consequences existing for higher risk procedures, such as spinal cord tumors, exist for lower risk, less complex surgeries. The relatively same structures and neural pathways are being manipulated in both cases, however the combination of certain patient and procedural factors may allow for an overall less invasive technique. Yet, complications during lower risk spinal surgery still vary greatly in their root cause, symptoms, and treatment (Deyo, Cherkin, Loeser, Bigos, & Ciol, 1992; Nasser et al., 2010).

Out of the overall family of spinal surgery complications, the primary group of interest is those procedures resulting in a patient awakening from surgery with a new neurological deficit (NND). NNDs are an outcome where a neurological structure succumbs to an iatrogenic injury, due to but not limited to: excessive manipulation, severance, temperature extremes, compression, lack of oxygen, or lack of blood supply (Fehlings et al., 2010; Møller, 2011). The consequences for patient who has a NND after spine surgery may be numbness, motor weakness, pain, or varying degrees of paralysis. Dependent upon the degree of injury, these consequences have the potential to be lifelong for a patient. However, even with such severe consequences, the frequency of these complications remain varied and complicated to appropriately categorize, track and report (Nasser et al., 2010).

Hamilton et al. (2011) offers the largest, multi-site study to date on NNDs after spine surgery. The authors retrospectively analyzed a prospectively administered, multicenter database for spine surgery and concluded out of 108,419 procedures, only 0.95 percent of patients incurred a NND. Approximately one percent does not strike most individuals as an opportunity for improvement, however the consequences of injuring any of these nervous system structures could result in catastrophic implications for the patient. Reducing this avoidable risk requires the utmost attention of the healthcare provider and the medical facility to not only reduce unnecessary costs, but to also reduce patient suffering (Deyo & Mirza, 2009; Sala, Dvorak, & Faccioli, 2007)

The NNDs documented by Hamilton et al. (2011) varied in frequency across anatomical structures, ranging from:

1. Nerve Root Injuries – 0.61 percent;
2. Cauda Equina – 0.07 percent;
3. Spinal Cord – 0.27 percent.

Injuring these structures during surgery can ignite several different consequences, for both the patient and the treatment facility. For the patient, NNDs can result in numbness, paralysis, pain, or all. These consequences may be transient in nature, or they may last a lifetime for the patient. Depending on the duration and severity of the NND, the patient may remain in the hospital for several additional days until the NND is treated surgically or allowed to resolve on its own under medical supervision. Another possibility is that the NND does not resolve, and the patient will require substantial assistance with the simplest day-to-day activities for the rest of their lives. The middle ground in between these two examples is the reality of the American population losing 83 million disability-adjusted life years due to lower back pain in 2010 (Resnick, Tosteson, Groman, & Ghogawala, 2014). Post-operative complications continue to threaten a hospital's ability to deliver high quality care. Spinal surgery patients succumbing to complications, especially NNDs, must be improved upon.

Complication Rates in Spine Surgery and Hospital Performance

Post-operative complications will continue to remain a significant area for attention and quality improvement for hospitals across the United States (Deyo & Mirza, 2009; Wang et al., 2012). Under the context of spine surgery, when combining the uncontrolled growth with the variable frequency of potentially life-long complications, this demands further analysis on behalf of physician and hospital leaders. This is especially true as our country faces a patient population unlike ever before. Our population of patients are living longer and also presenting with more complex preoperative comorbidities, increasing their chances of surgical complications during spine surgery. (Missios & Bekelis, 2015; Ney et al., 2015; Puffer, Planchard, Mallory, & Clarke, 2016; Wang et al., 2012).

These concerns regarding spinal surgery and its patients are highlighted by recent findings from the Agency for Healthcare Research and Quality (AHRQ) showing spinal surgeries having the sixth highest aggregate cost for hospital stays in 2011, upwards of $11.218 billion dollars (Torio & Andrews, 2006). A significant portion of these costs are avoidable via preventing surgical complications and their related post-operative consequences. Uncontrolled post-operative complications have the high likelihood of influencing the total economic impact of spinal surgery and reducing overall profitability for a hospital especially under the growing trends of bundled payments and value based reimbursements (Bernatz & Anderson, 2015; Khanna et al., 2015; Puffer et al., 2016).

A growing trend in assessing a hospital's cumulative performance in spine surgery is to measure the LoS and 30DRR for individual patient encounters (Marquez-Lara, Nandyala, Fineberg, & Singh, 2014; Yadla et al., 2015). LoS is simply the measurement of total days in the hospital from the time patients are admitted to the time they are discharged. 30DRR is a metric that begins after the LoS has ended, and is defined as a readmission to an inpatient treatment facility after the initial discharge (Samuel et al., 2016).

LoS. The advocacy behind LoS as a hospital metric of spine surgery continues to grow in popularity for a multitude of reasons. This popularity spans across all stakeholders in spine surgery, including the patient, provider, hospital and payer. From a patient and hospital standpoint, the less time a patient is in a hospital, the less likely a patient will contracts hospital borne illness or be injured from a fall or medical error (Kollef, 2000; Trouillet et al., 1998). From a patient and payer standpoint, each additional day not spent in the hospital after surgery saves approximately $1,000 per day of inpatient hospital charges (Gruskay, Fu, Bohl, Webb, & Grauer, 2015). In addition, patient satisfaction increases when patients are discharged quicker and allowed to return home faster (Missios & Bekelis, 2016a). LoS and post-operative complications are relatively well linked. Patil, Lad, Santarelli, and Boakye (2007) concluded patients who undergo spinal surgery and incur a post-operative complication will increase their consumption of vital hospital resources they otherwise would not have needed.

Moving from a patient's to a hospital's perspective, LoS is very important for determining appropriate strategies for newly developing diagnosis related groups (DRGs) and value based care (VBC) payment reform initiatives (Puffer et al., 2016; Resnick et al., 2014). DRG and VBC contract strategies are well navigated when the hospital understands what is driving certain patient populations to utilize more resources than others, therefor allowing a hospital to optimize their reimbursements per specific DRG and VBC agreements. Having predictive models for patient LoS in spine surgery also allows a hospital to better plan for day-to-day hospital resource utilization and expenditures.

While there are significant proponents of LoS as a hospital performance indicator, to ignore the opposing views of LoS being a meaningful quality indicator would be inappropriate. The lack of support for LoS as a performance metric varies largely around its relationship to complications, post-operative care, and intensity of care (Goodney, Stukel, Lucas, Finlayson, & Birkmeyer, 2003; Krell, Staiger, & Dimick, 2014; Rosen et al., 2016). There are ongoing discussions questioning whether LoS adequately representing true measures of complications from spine surgery. These collective authors suggest there are additional confounding variables in the current body of literature, such as patient comorbidities, that have not been adequately explored to suggest complications are solely correlated with influencing LoS. Additionally, Taheri, Butz, and Greenfield (2000) oppose the populous viewpoint of LoS increases correlating with increased costs for hospitals and insurers, and they find the costs associated with additional days of LoS only surmount to three percent of additional costs.

30DRR. As a hospital performance indicator, 30DRR continues to receive significant attention and discussion from the highest echelons of the American healthcare system and for good reason. Goodman, Fisher, and Chang (2013) justify this attention through their analysis yielding one in eight postoperative patients are readmitted, costing CMS nearly $28 billion per year. Officially codified in section 3025 of the Patient Protection and Affordable Care Act (PPACA) is an initiative to address the ballooning economic impact behind readmissions, and it is called the Hospital Readmissions Reduction Program (HRRP). Beginning in fiscal year 2013, the HRRP incentivizes hospitals, through fiscal penalties, to reduce avoidable thirty day readmissions in common medical conditions. These penalties are assessed to upwards of three percent of a hospital’s total Medicare reimbursement (Dimick & Ghaferi, 2015; Gonzalez, Shih, Dimick, & Ghaferi, 2014).

The HRRP continues to grow in breadth, and as of 2015 CMS will increase fiscal penalties to additional post-operative conditions and surgical procedures, specifically the coronary artery bypass graft (CABG) surgery (Joynt, Figueroa, Oray, & Jha, 2016; Zuckerman, Sheingold, Orav, Ruhter, & Epstein, 2016). Initial assessments of HRRP’s utility have come back with promising results yielding significantly downward trending 30DRR for hospitals who previously displayed excessive thirty day readmissions (Lu, Huang, & Johnson, 2016). In addition to governmental attention, Winborn, Alencherril, and Pagan (2014) highlight the general public’s understanding and agreement of the 30DRR as a performance metric of hospitals.

While most of the attention on 30DRR originates from governmental payers who are primarily concerned with their own beneficiaries, 30DRR is supported in the literature as a performance metric of heavy interest in lower risk spinal surgeries (Akins et al., 2015; Khanna et al., 2015; Kim, Smith, Lim, Cybulski, & Kim, 2014). This interest, similar to LoS, is driven from the variety of individuals associated with the spinal treatments to include patients, physicians, medical facilities, and payers. Unplanned 30DRR represent complications of care in the eyes of healthcare professionals, yet even with significant technological advances in treatments. One would expect with advanced technological care surgeries would experience a decreased 30DRR, yet unfortunately 30DRR have remained relatively stagnate (Adogwa et al., 2016).

Similar to LoS, there are several opponents of using 30DRR as a measure of hospital on surgical procedures. Epstein (2009) and Samuel et al. (2016) suggests that

30DRR may not truly represent quality problems in a patient’s intraoperative care. Instead, the authors support pre and post-operative variables, such as patient selection, aggressive referrals, and discharge planning play larger roles in a hospital’s 30DRR. Accurately calculated 30DRR, similar to LoS, is heavily dependent upon hospital administrative data, and the calculations for these metrics will only be as good as the data is collected. Goff, Pandey, Chan, Ortiz, and Nichaman (2000) identified shortfalls relying on hospital administrative data too heavily, and their conclusions yielded that almost one-third of patients were discharged with incorrect International Classification of Diseases (ICD). These types of discharge miscalculations would misrepresent the root causes behind 30DRRs.

For the better or the worse, LoS and 30DRR will remain variables of significant interest in assessing hospital performance in spinal surgeries. As hospital administrative datasets continue to grow and refine their use, especially AHRQ’s Healthcare Cost and Utilization Project (H-CUP) National Inpatient Sample (NIS) and the State Inpatient Database (SID), and Truven Marketscan, retrospective literature will concurrently grow and yield stronger validity. Outcome management continues to drive national and state level health policies attempting to address quality of care. As reimbursement reform continues to aggressively evolve further into pay for performance, or pay for value, successful hospitals need to be distinctly acute towards accurately documenting and optimizing their patient’s LoS and 30DRR.

Reducing Surgical Complications with Intraoperative Neuromonitoring

Techniques for reducing surgical complications in lower risk spinal surgery can be accomplished in a variety of ways. Physicians and hospital administrators have a multitude of resources at their disposable addressing pre, intra, and post-operative considerations of spinal surgery complications. For a pre-operative example, patients with a higher body mass index (BMI) have shown to have higher post-operative surgical complications (Schoenfeld et al., 2011). Physicians may mandate patients who require spinal surgery that they must achieve a pre-determined BMI before the surgeon will proceed. The literature also supports a post-operative discharge planning can reduce spinal surgery complications (Deyo et al., 2010). A hospital who invests in best practices in discharge management could significantly benefit from their spinal surgery patients having shorter LoS and 30DRR. In addition to pre and post-operative techniques to reduce surgical complications, there are highly technical intraoperative services available to assist surgeons and hospitals to reduce their surgical complications and improve their facilities performance on quality metrics, such as LoS and 30DRR.

Introduction and history of IONM. Intraoperative Neuromonitoring (IONM) is a health service designed to reduce the risk of intraoperative surgical injuries that may potentially manifest as post-operative complication for patients undergoing spinal surgery. IONM provides risk reduction by communicating real-time, functional, electro-neurodiagnostic information to the surgical team, collected directly from the patient. This intraoperative neurological data includes but is not limited to: sensory and motor function of the spinal cord and brain, spinal nerve root activity, and critical blood perfusion for neuronal structures and pathways (Møller, 2011).

The tenants of IONM did not start with protecting patients undergoing spine surgery in operatory setting. The foundations of current day IONM find way their back to as far as the early 1940s for patients suffering from seizure disorders. Drs. W. Penfield and H. Steelman were the first to publish results treating focal epilepsy by using electroencephalography (EEG) to localize seizure activity in a patient's brain (Penfield & Steelman, 1947). In those same years, the first description of somatosensory evoked potentials (SEPs), widely used today in most IONM procedures, is described and analyzed by George Dawson in 1947 as a means to test a patient's sensory pathway functioning (Hauck, 2015). Fast forward a few decades to the 1960s, before the expansion of spinal surgery, and you will see IOM as a small niche service, providing auditory brainstem responses (ABRs) and electromyography, to protect a patient's post-operative hearing and facial function after undergoing brain tumor resections (Møller, 2011). Following shortly thereafter, the IONM industry begins to truly establish itself through the use of somatosensory evoked potentials (SEPs) to monitor the functional integrity of spinal cords during Harrington rod instrumentation for scoliosis corrections (Zouridakis & Papanicolaou, 2001).

The original idea of solely SEPs protecting the thoracic cord during scoliosis corrections remains valid today (Glover & Carling, 2014). However, IONM has now evolved into multi-modality monitoring, offering protection of both the sensory and motor tracts of the spinal cord and certain brain structures. This has influenced IONM professionals monitoring procedures across a multitude of surgical disciplines: brain surgery, adult spine surgery, pediatric deformities, vascular surgeries, and even otolaryngology (Lall et al., 2012). IONM consists of three primary functions: the surgical neurophysiologist located inside the operating room responsible for the technical data gathering (technical component), the interpreting physician who interprets the data to make medical interventions (professional component), and the physical machinery and equipment connected to the patient. The risk reduction afforded through the combination of highly skilled surgical neurophysiologists and physicians creates an attractive yet expensive service for surgeons and hospital administrators. The IONM team utilizes electrophysiological, differential amplifiers to collect their data, and this data can be transmitted to the appropriately credentialed physicians via tele-medical infrastructure. The combination of these three functions above create the IONM team who have shown to reduce surgical risk, decrease post-operative complications, and lower overall cost of care of high risk spine surgery (Ney et al., 2015; Ney et al., 2013; Nuwer et al., 2012)

Clinical practice of IONM. The moment a patient enters the operatory room their surgical risks begin as patient positioning can put large neural structures at risk for injury, especially in time intensive surgeries. The surgeon and the remote IONM physician achieve consensus on the appropriate IONM modalities to deploy for the particular spinal procedure. Current day literature supports the proposal of providing multimodality monitoring for the majority of spine surgeries (Fehlings et al., 2010). Multimodality monitoring includes providing the following services: in the form of somatosensory evoked potentials (SSEPs) and transcranial moto evoked potentials (TcMEPs), and electromyography (EMG). These three intraoperative tests provide the surgical and IONM team insight into a patient’s sensory and motor functional status.

The functional data is collected by the surgical neurophysiologist present in the room. Ideally, the IONM data is first collected after the patient is anesthetized and before the patient is positioned for surgery, and this data collection continues through the closing of the surgical wound. During the entirety of this start to finish level of protection, the IONM team is relaying information that may alter the surgeon's approach and specific technique (Macdonald, 2006; Mendiratta & Emerson, 2009). The data may also force corrective measures to intervene on the patient's behalf such as removal of insulting medical implants, increasing hemodynamic perfusion, adjusting anesthetic levels, or even reposition the patient's body on the operatory bed. The combination of real time data collection and intraoperative recommendations allows the surgical team act upon this information to deliver interventions to reduce any potential complication. Through these interventions ONM assists physicians and hospitals conduct safer spinal surgery allowing a reduction of intraoperative complications leading to less post-operative deficits (Cole et al., 2014; Fehlings et al., 2010; Husain, 2015; Ney et al., 2015).

There is considerable geographical variance in the clinical and regulatory practices of IONM. There is not state licensure system for IONM professionals, and the field solely relies on professional societal certifications, such as the Certification in Neurophysiologic Intraoperative Monitoring (CNIM) and the Diplomate of the American Board of Neurophysiological Monitoring (DABNM). These are the primary certifications the IONM professionals rely upon to display competence in the field. However, these independent certifications are governed and administered by two different organizations: the American Board of Registered Encephalographic Technologists (ABRET) and the American Society of Neurophysiological Monitoring (ASNM). With no centralized governing authority at the state or national level, industry level societies are relied upon for credentialing and also setting industry clinical standards. The IONM industry has historically followed the clinical guidance from the American Clinical Neurophysiology Society (ACNS). These guidelines act a larger framework for IONM professionals to operate within, however IONM companies and hospitals department display a significant variety of practice within ACNS' framework.

Business practice of IONM. IONM services are widely available across the United States. Third party, contracted providers dominate the market share of IONM services rendered across the country. Hospitals also have their own internal IONM departments staffed with hospital employees. Both delivery models monitor spinal procedures on a regularly basis. Magit et al. (2007) engaged a broad cross section of orthopedic surgeons from the United states and the author's conclusions confirm IONM services are widely available and easy to access if a surgeon or hospital so desires.

Similar to IONM's clinical practices, its business execution is also widely variable, and the emerging literature highlighting utilization and growth rates of IONM requires continued analysis. In a recent national retrospective study utilizing the Truven Marketscan dataset, Cole et al. (2014) demonstrated IONM being utilized on approximately thirteen percent of single-level spinal procedures. In a similar analysis, Hamilton et al. (2011) analyzed 108,419 procedures inside the Scoliosis Research Society (SRS) national database, and the author's results yielded IONM was used in approximately 65 percent of all the spinal surgeries. Both examples highlight a wide spectrum of utilization rates at both the procedural and regional levels of analysis.

Benefits of IONM on spinal surgeries. Various studies recognize IONM contributing to positive patient outcomes across a variety of spinal procedures including: spinal cord tumor resections, multi-level deformity corrections, and even less complex single level procedures (Cole et al., 2014; Hawksworth et al., 2015; Lall et al., 2012; Ney et al., 2015; Ney et al., 2013; Rho, Rhim, & Kang, 2016; Sala & Di Rocco, 2015).

For a large cross section of these spinal surgery patients, IONM can be indicated for use by the surgeon or by hospital policies. Hospital and surgical practices greatly benefit when they can defend their service line operations to regulators, payers, and their medical staff (White, 2016). IONM has been shown to be highly predictive of potential intraoperative complications, and also to reduce neurological injuries in high risk spinal surgery across a multitude of procedures (Fehlings et al., 2010; Nuwer et al., 2012; Sala & Di Rocco, 2015).

The literature is less robust in specifically addressing the benefits of IONM with its use on lower risk spinal procedures, and literature is available does not lend consensus on the IONM's effectiveness on lower risk spinal procedures. Just until the last few years have authors, such as Nuwer, Ney, and Cole began to analyze IONM's effect on outcomes and hospital performance for less complex spinal procedures.

IONM, complications, and lower risk spinal surgery. In higher risk procedures, such as spinal cord tumors and large deformity corrections, longitudinal and meta-analysis based evidence, strongly supports IONM reducing patient complications (Korn et al., 2015; Rho et al., 2016; Sala & Di Rocco, 2015; Scibilia et al., 2016; Thuet et al., 2010). However, the literature supporting IONM reducing patient complications in lower risk procedures is still emerging and requires further development. A landmark study conducted by Ney et al. (2015) analyzed the Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS) discharge database which included 234,067 individual discharges from their inclusion criterion. The authors' results yielded less complex lumbar laminectomies and fusions who utilized IONM endured lower rates of NND than those procedures who went without IONM services, 0.8 vs 1.4 percent respectively. In a similar national database analysis, capturing 85,640 patients in their inclusion criterion, Cole et al. (2014) displayed reduced NND rates in procedures who used IONM on simple lumbar laminectomies vs those procedures who did not use IONM, 0.0 vs 1.18 percent respectively. Additional meta-analyses of four class I and seven class II studies by Nuwer et al. (2012) establish IONM as "effective to predict an increased risk of the adverse outcomes of paraparesis, paraplegia, and quadriplegia in spinal surgery".

IONM and economic impact of spine surgery. Moving on from the clinical benefits of IONM's use on lower risk procedures, there are also economic advantages to using IONM. By avoiding intraoperative complications and thus post-operative deficits, IONM has the potential to save hospitals, insurance companies and patients significant long-term costs. As a baseline to understand the global costs of IONM, the combination of technical and professional costs of IONM can range anywhere from $200 to $5,000 per procedure (Cole et al., 2014; Ney et al., 2015; Sala et al., 2007). Under the context of insurers, Ney, van der Goes, and Watanabe (2012) established the first economic decision model addressing IONM's value in spine surgery. The author's model calculated savings to third party payers in the amount of $63,387 per each NND avoided through the use of IONM. The economic benefit to the patient is shown in a simulated data model by Ney et al. (2013). The authors demonstrated using IONM on spinal surgeries reduced mean lifetime healthcare costs by $23,189 more than spinal surgeries who did not use IONM (Ney et al., 2013).

IONM, LoS, and 30DRR. The literature is lacking significant data regarding IONM's influence over LoS in lower risk spinal procedures. Cole et al. (2014) demonstrated patients undergoing lumbar discectomies and ACDFs with IONM had a LoS of 0.11 days less than those patients who did not have IONM. Ney et al. (2015) demonstrated an adjusted LoS of 0.26 days less for less complex spinal procedures who utilized IONM than procedures who did not.

While there is a significant body of literature researching 30DRRs for spine surgery, the literature does not speak to IONM's influence on 30DRR on less complex spine surgery. Similar to the lack of data supporting IONM's influence on LoS, the data supporting IONM's influence on 30DRR also needs further analysis. What sparse data is available suggests IONM has been shown to have minimal effect on 30DRR in less complex spinal surgeries. ACDF procedures utilizing IONM had a minimal reduction of 0.15 percent in all-cause 30DRR compared to procedures who did not use IONM (Cole et al., 2014).

It is important to discuss the potential relationship between LoS and 30DRR. These variables can be viewed as dependent or independent of each other, and the competing views are driven by a multitude of factors such as procedures, patient demographics, and surgical techniques. For example, some would suggest if a patient has a longer LoS their likelihood to be readmitted is predictably smaller since they received such concentrated care for duration after their discharge. An alternate hypothesis would reverse this, and suggest a shorter LoS for a patient puts them at higher risk for a 30DRR, suggesting the lack of adequate post-operative care would result in increasing readmissions. The discussion surrounding LoS and 30DRR is relatively well explored in procedures outside the spine surgery service line, and it has been supported that LoS and 30DRR are independent variables in heart and pulmonary admissions (Kaboli et al., 2012). Conclusions reached by Martin, Street, Han, and Hutton (2016) in their analysis of a collection of general surgery procedures also support LoS and 30DRR can be mutually exclusive of each other.

Hospital Volume and IONM Utilization

For over thirty years, health services and economics research continues to explore the relationship between the volume of a service and the connected patient outcomes (Lee, Sethuraman, & Yong, 2015). The research explores a common notion in professional practices, especially in medicine, that "practice makes perfect." This is phrase is embodied to such a degree that physicians, to this day, continually label themselves as practitioners of medicine, inferring the glass ceiling will never be broken with perfecting medicine. The notion that practice makes perfect can be scientifically analyzed in surgical settings as well. This analysis takes the shape of the relationship between volume and patient outcomes. There is support suggestive of medical environments and practitioners that practice specific procedures often have more positive patient outcome, such as lower mortality rates (Brevig et al., 2015; Merrill, Jha, & Dimick, 2016). However, the specific factors behind this connection remain elusive and without a true root cause identified (Ghaferi, Birkmeyer, & Dimick, 2011). Nonetheless, the decades of research investigating this correlation between volume and outcomes continues to be an area of excitement, especially in surgical services such as spinal care.

Naturally, being one of the highest utilized procedures across the American healthcare system, there are ample opportunities to test the theory of “practice makes perfect” specifically under the context of spine surgery. The literature supporting this theory is rather suggestive of volume having a credible connection to positive patient outcomes across a variety of procedures:

1. Pediatric deformity corrections were observed having more complications in lower volume settings compared to high volume settings (Paul, Lonner, & Toombs, 2015);
2. Adult deformity revision surgeries conducted by high volume surgeons and high volume centers yielded lower perioperative complications (Paul, Lonner, Goz, et al., 2015);
3. Adult lumbar spine surgery displayed lower mortality and complication rates when conducted by high volume surgeons and hospitals (Bederman et al., 2009; Farjoodi, Skolasky, & Riley, 2011).

While there is significant evidence linking surgical volume with higher outcomes, the hypothesis also generates opposition. Mehrotra and Dimick (2015) discovered outcomes for procedures conducted at spinal surgery centers of excellence did not have a statistically significantly difference in outcomes compared to facilities without the center of excellence designation.

Across diverse patients with various ages and procedures, there is support for the notion of higher quality, i.e. positive patient outcomes, is more than likely found with high volume surgeons and high volume medical facilities. Defining specific levels determining what is “high volume” vs “low volume” may prove problematic for certain circumstances. However insurance companies such as Aetna and Blue Cross Blue Shield (BCBS) award “distinction status”, aka high volume, under the following criterion (Brevig et al., 2015):

1. Surgeons who performs over fifty spine surgeries in a year;
2. Medical facilities who perform 100 procedures per year (BCBS);
3. Medical facilities who perform 200 procedures per year (Aetna).

These criterion are based off the supporting evidence suggesting the best spinal surgery outcomes are observed in facilities with a minimum of 100 spinal fusions per year (Brevig et al., 2015).

The literature is beginning to dissect the many variables involved behind IONM’s utilization at the hospital level of analysis. The landmark studies by James et al. (2014), Ney et al. (2015) are the first in the field to scratch the surface of the demographics of the medical facilities who utilize IONM. The authors both concluded: IONM displayed significant year over year growth across the nation, IONM is more likely to be used in the western United States on less complex spinal procedures, and more likely to be used in Academic Medical Centers (James et al., 2014; Ney et al., 2015).

Taking this line of questioning one step further shows there is a gap of evidence supporting any type of inter-facility comparison on higher vs lower IONM utilization. The notion previously discussed suggesting the more a service is used the higher probability of better patient outcomes is an attractive idea to analyze for IONM. There is no data comparing hospitals of various IONM utilization rates to better understand what context IONM, if any, provides more frequent positive patient outcomes. Exploring the comparison of high vs low IONM utilization from hospital to hospital will afford physician and hospital leaders:

1. A better understanding of best practices of their surgical service lines;
2. Better understanding of the context and performance metrics IONM can potentially contribute to;
3. Ultimately will add to the current body of literature so desperately needed to substantiate IONM's services moving into the future.

All data for this study is derived from the Healthcare Cost and Utilization Project (HCUP) State Inpatient Data (SID) databases. provided by the Agency for Health Research and Quality (AHRQ). The HCUP SID databases include discharge records from community hospitals across the respective participating states. The SID datasets capture all patients, regardless of third party payer, and together encompass approximately 97 percent of all U.S. community hospital discharges.

Conclusions

As healthcare policy continues to evolve and embrace concepts such as value based care, bundled payments, and pay for value reimbursement strategies, all stakeholders must be acutely aware to the services they are utilizing. This especially means physician and hospital leadership are better served when they not only understand how each dollar is spent and the related return on such investments, but also understand the specific variables and contexts of the services they utilize. Understanding these variables of influence in patient care and their relationship to meaningful, positive patient outcomes will be essential for successful navigation of the many current and upcoming value based payment reform initiatives (Saleh & Shaffer, 2016).

This need to understand is especially true for the rapidly growing specialty of spinal treatments and their interrelated support services. The justification of IONM in lower risk spinal procedures still lacks vast stakeholder consensus, especially across surgeons, payers, and industry leaders. IONM's influence on positive, post-operative outcomes for less complex spine surgery requires further exploration (Fehlings et al., 2010; James et al., 2014; Lall et al., 2012). The literature displays mixed results, with various classes of evidence, supporting IONM as a meaningful contributor to spinal procedures. These results are highlighted with a severe contrast between such low margins of risk yet with dramatic consequences. The available body of literature speaking to IONM's relationship to the hospital performance metrics, of LoS and 30DRR, on lower risk spinal procedures is minimal at best. The literature reviewed displayed a dearth of knowledge regarding the relationship between medical facilities who use IONM in high volume settings versus facilities that do not. There is well established evidence to suggest high volume facilities have more positive patient outcomes in general, and due diligence is required to better understand if IONM displays a similar relationship in high and low volume surgical settings.

CHAPTER III
METHODOLOGY

Study Design and Hypothesis

This study included a retrospective analysis of spinal procedures contained within MS-DRG codes 459, 460, 471, and 473 to examine the relationship between IONM use during lower risk spinal procedures on length of stay (LoS) and 30-day re-admission (30DRR), controlling for variables influencing inter-hospital performance. The primary aim of the study was to compare the impact of IONM use during lower risk spinal procedures on the LoS and 30DRR rates between hospitals with both high and low volume of IONM of spinal procedures. At the patient level, other factors related to LoS and 30DRR, such as patient race, ethnicity, sex, age, payer source, socioeconomic status, and comorbidities were controlled. At the hospital level analysis, hospital size, hospital city and state, regional location, teaching status, rural or urban designation, and control or ownership were included as covariates.

Research hypotheses were constructed using the hospital as the unit of analysis. This study specifically analyzed the influence of IONM in high- and low-utilizing hospitals on LoS and 30DRR outcomes for low risk spinal surgeries. The four hypotheses were:

> ***Hypothesis 1:*** Hospitals with a high rate (> 67th percentile) of IONM use will have lower mean length of stay (LoS) than hospitals with low use (< 33rd percentile) of IONM.
>
> .Rationale: Availability of and regular use of IONM in an institution may be expected to increase the likelihood of IONM use for all patients that may benefit,

this would be expected to reduce the number of adverse surgical events that occur, with an overall effect of improving mean LOS for the population.

Hypothesis 2*:* Hospital with high rate (> 67th percentile) of IONM use will have lower 30-day readmission rates than hospitals with low use (< 33rd percentile) of IONM.

Rationale: IONM reduces adverse surgical events that require readmission for correction.

Hypothesis *3:* High surgical volume hospitals with a high IONM use rate (>67th percentile) of IONM will have shorter mean LoS when compared to high surgical volume hospital with low rate of IONM use.

Rationale: Organizational practice patterns that routinely include use of IONM for low risk spinal surgery leads to better integration of this technology into surgical routines, increases team experience and leads to fewer adverse surgical effects, lower LOS and decreased population risk of readmissions.

Hypothesis H_4. High surgical volume hospitals with high IONM use rate (>67th) during low risk will have lower 30-day readmission rates than similar high volume hospitals with low IONM use.

Rational: Medical facilities who demonstrate high volumes of spinal surgeries have documented better surgical outcomes. Comparing facilities with high volume of lower risk spinal surgery who utilize IONM against facilities who also have high rates of lower risk spine surgery but who do not utilize IONM, will show the benefit of IONM separate from the effect of surgery volume

Population and Sample

Figure 1.1 reflects all 2012 inpatient discharges from Florida, Massachusetts, New York, and Washington classified under MS-DRGs 459, 460, 471 and 473 included in this study sample. The data were obtained from the archival database maintained by the Agency of Healthcare Quality and Research (AHRQ) Healthcare Cost and Utilization Project (H-CUP), State Inpatient Databases (SID). The HCUP SID is a de-identified dataset that can be purchased by investigators in academic institutions under a Data Use Agreement for specific, approved research studies. The Medical University of South Carolina's (MUSC) Institutional Review Board (IRB) classified this study as exempt from human subjects review.

Data is made available for this research study through an agreement between H-CUP and Dr. Kit Simpson, Professor and Director of the of the Comparative Effectiveness and Data Analysis Research Resource (CEDAR) at the Medical University of South Carolina (MUSC).

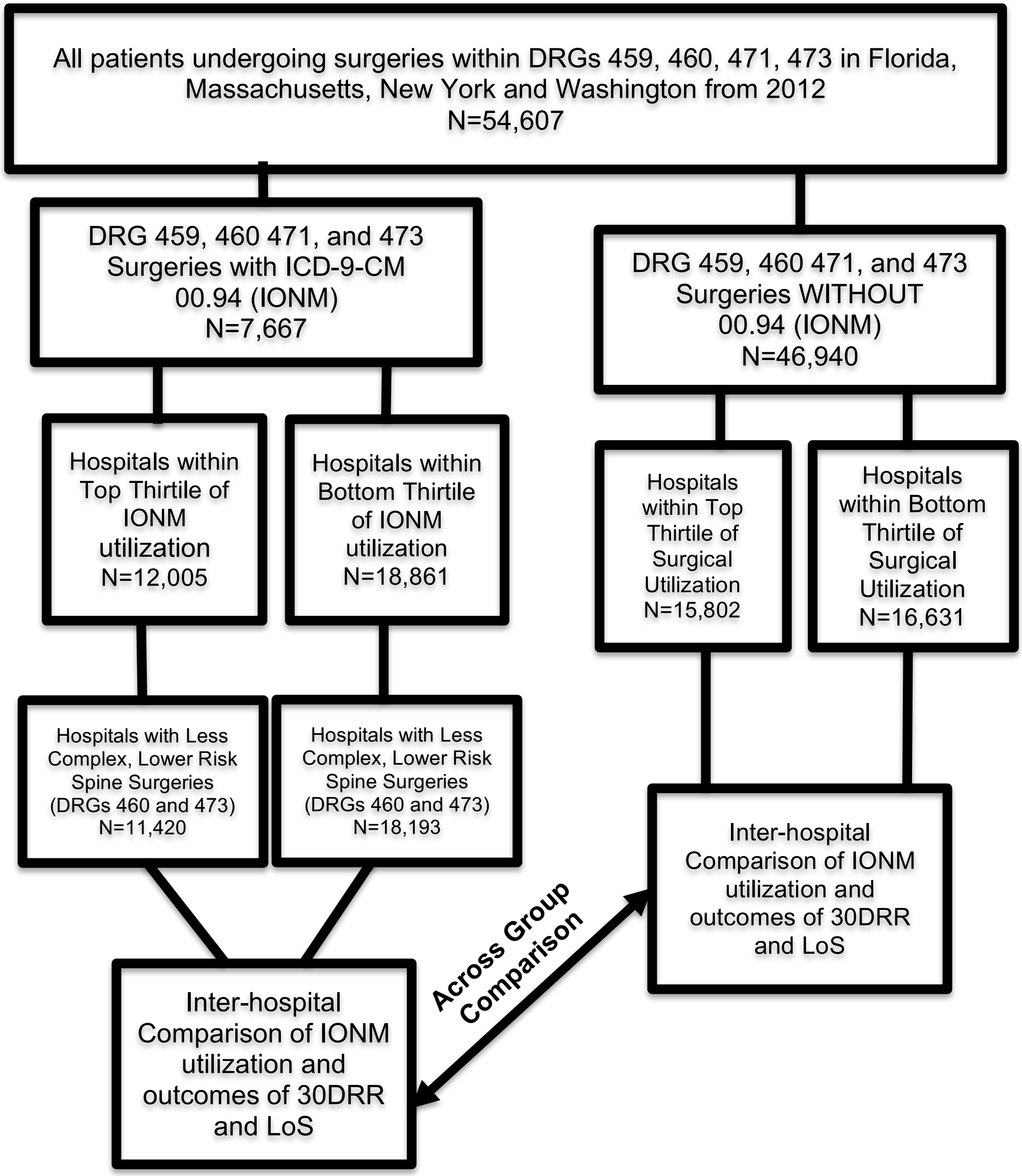
The criterion for this study sample were hospitals with patients categorized within DRGs 459, 460, 471 or 473, and with IONM ICD-9-CM procedural code 00.94. The included DRGs are the following:

1. DRG 459 – Spine fusion outside the cervical region, with major comorbidities and/or complications;
2. DRG 460 – Spine fusion outside the cervical region without major comorbidities and/or complications;
3. DRG 471 – Cervical fusion with major comorbidities and/or complications; and,
4. DRG 473 – Cervical fusion without comorbidities or complications.

These DRGs capture both low risk and high risk spinal procedures in both the lumbar and cervical spine. For the purposes of this study, DRGs 460 and 473 were considered low risk, less complex spinal surgeries and DRGs 459 and 471 were considered higher risk, more complex spinal surgeries. ICD-9-CM procedural code 00.94 identified hospitals whose patients received IONM services. Procedures under any remaining MS-DRGs were excluded because they reflected alternative procedures not included in this study. Examples of these excluded procedures were: spinal fusions spanning four or more levels, spinal cord tumor resections, vertebral compression fractures, and any procedure combining both an anterior/posterior surgical approach.

Figure 1.1.

Inclusion and Exclusion Criterion for Hospital IONM Utilization Thirtile Comparison.



Definition of Variables

LoS for the index admission and 30DRR for less complex spinal procedures were outcome variables. LoS was classified as a continuous variable reported in estimated means. LoS was measured in days from the time the patient was admitted for surgery until the time the patient was discharged. Thirty day re-admission was operationalized as any patient discharged from the index hospitalization who was readmitted to a medical facility before 31 days (Khanna et al., 2015). Thirty day readmissions were reported as Odds Ratios (ORs).

At the patient-level, predictor variables included documented pre-operative comorbidities and post-operative complications, Charlson score, age, sex, race, ethnicity, payer source, and socioeconomic status. At the hospital-level, IONM utilization rates were classified into thirtiles for analysis. The top thirtile of IONM utilization was compared to the bottom thirtile of utilization. Additional hospital variables, classified as categorical variables, were assessed including region, location, ownership.

Data Analysis

Univariate analysis was conducted to examine the distribution of the patients captured under DRG 459, 460 471, and 473 and ICD-9-CM 00.94 (IONM) for age, sex, race, ethnicity, comorbid conditions, hospital characteristics, income quartile, third party payer, and chronic conditions. Total annual IONM utilization was analyzed for DRGs 459, 460, 471, and 473. Additional univariate analyses were conducted to examine whether patient and hospital characteristics varied across hospital IONM utilization thirtiles.

Differences in proportions, means and/or medians for the variables of interest across IONM use thirtiles were analyzed using the independent samples *t* test and Pearson $X^{2.}$

30DRR Analysis. Multivariable, logistic regression comparison was performed to assess the association between IOMN use thirtile and hospital 30-day readmissions, while controlling for a multitude of patient and hospital characteristics. Regression models included Charlson score, age, sex, income, payer source, and hospital locations as covariates. The logistic regression analysis was adjusted for any imbalance in effect of covariates for both patient and hospital characteristics. Results from the multivariable regression model were reported using odds ratios (ORs) and 95% confidence intervals (CIs). Significance was set at alpha $\leq$ 0.05.

LoS Analysis. An estimated mean hospital LoS was calculated using a gamma distributed, generalized linear log linked, multivariable regression multiple. The log-link regression analyses were used in place of linear regression because LoS was not normally distributed and highly skewed. Discharges with a LoS equal to zero were assigned a value of 0.0.1 to satisfy the log-link requirement. The model adjusted the LoS estimates for any effect of imbalance in patient and hospital characteristics for the IONM groups. The log-link model generated effect sizes in days with 95% confidence intervals.

All statistical testing was performed using a combination of Statistical Analysis Tool (SAS) v9.4 (SAS Institute, 2016) and the Statistical Package for the Social Sciences (SPSS) v24.0 (IBM Corporation, 2016).

CHAPTER IV
RESULTS

Introduction

As stated in Chapter 1, the primary purpose of this study was to analyze the relationships between different hospital utilization rates of IONM and IONM's influence on the hospital outcomes of 30DRR and LoS. This chapter is organized in terms of the four specific research hypotheses posted in Chapter 1, and the corresponding statistical analysis and results for each hypothesis.

To examine any potential relationship between hospital use of IONM and hospital outcomes, patient discharge records from four 2012 AHRQ HCUP Statewide Inpatient Databases (FL, MA, NY, and WA) were used. These states were selected based on the availability of HCUP SID databases at the Medical University of South Carolina, and also due to the higher quality data for 30-day readmissions contained within each respective state. A combination of statistical packages including SPSS and SAS were used for this analysis. Sample descriptions for the entire dataset were calculated and reported by frequency, means and medians where appropriate. Univariate comparisons between each independent variable and outcome across the top and bottom IONM utilization thirtiles were examined to identify preliminary relationships between study variables. Next, multivariable log link and logistic regression procedures were used to test the association between hospital utilization thirtiles of IONM for lower risk, less complex spinal surgeries (DRG 460 and 473) and 30DRR and LoS, respectively. The relationship between IONM use thirtiles and 30DRR and LoS were also estimated for all hospitals conducting spinal surgeries.

Patient Characteristics

A total of 54,607 patient discharge records from the HCUP SID yielded the following distribution across the following DRGs: 459 (Spinal fusion except cervical with major comorbidities, N=1,299), 460 (Spinal fusion except cervical without major comorbidities, N=31,610), 471 (Cervical fpinal fusion with major comorbidities, N=1,116), and 473 (Cervical spinal fusion without major comorbidities, N=20,582), respectively. The distribution for each variable included in this study is included in Table 1.1. Briefly, 5,603 (10.3%) of discharged patients were readmitted within 30-days and the average LoS was 7.41 days (SD=3.28). The mean total cost per discharge was $22,992 and IONM was used on 7,667 procedures. The majority of patients were Caucasian (78.3%) and female (53.2%) with an average age of 57.07 (sd=13.89) years. The average Charlson score was .30 (sd=.69). Private insurance (42.6%) was the largest payer source followed by Medicare (36.9%). Patient median household income quartiles were relatively well balanced across all four quartiles, with the first quartile being the least represented (19.8%).

Hospital Level Characteristics

The mean total charges for all procedures was $85,535 (sd=57,568), mean IONM use was 14.77%. More than half (60.55%) of procedures were conducted in a not-for-profit, urban hospital with 300 or more beds followed by smaller not-for-profit, urban hospitals with 100-299 beds (19.84%). Florida contained the majority (44.0%), of the hospitals in the study with Massachusetts only yielding 10.0%.

Table 1.1

Patient and Hospital Thirtile Characteristics Across Sample, N=54,607.

	N(%) or Mean(SD)
MS-DRG Code	
459	1,299 (2.4)
460	31,610 (57.9)
471	1,116 (2.0)
473	20,582 (37.7)
IONM Use – Hospital	7,667 (14.0)
IOM Percentiles	
Top 1/3 of utilizers	12,005 (25.16)
Middle 1/3 of utilizers	16,857 (35.32)
Bottom 1/3 of utilizers	18,861 (39.52)
Non-IOM Percentiles	
Top 1/3 of utilizers	15,802 (33.11)
Middle 1/3 of utilizers	15,290 (32.04)
Bottom 1/3 of utilizers	16,631 (39.52)
Total Cost in Dollars (Mean; SD)	22,992 (14,958)
Length of stay in days (Mean; SD)	3.15 (3.28)
30 Day Re-admission	5,603 (10.3)
Patient Level Factors	
Race / Ethnicity	
White	4,780 (78.3)
Black	3,846 (7.0)
Hispanic	3,725 (6.8)
Asian or Pacific Islander	633 (1.2)
Native American	131 (.2)
Other	2,778 (5.1)
Sex	
Male	25,575 (46.8)
Female	29,032 (53.2)
Age (Mean, SD)	57.07 (13.89)
Payer Source	
Medicare	20,151 (36.9)
Medicaid	3,336 (6.1)
Private insurance	23,250 (42.6)
Self-pay	659 (1.2)
No charge	7,083 (13.0)
Socioeconomic Status (Median Household Income Quartiles)	

First quartile	10,806 (19.8)
Second quartile	14,075 (25.8)
Third quartile	14,756 (27.0)
Fourth quartile	13,849 (25.4)
Charlson Score (Mean, SD)	.30 (.69)
Hospital Factors	
Location	
Florida	24,037 (44.0)
Massachusetts	5,447 (10.0)
New York	17,815 (32.6)
Washington	7,308 (13.4)
Total Charges (Mean, SD)	85,535 (57,568)
IOM Percentage (Mean, SD)	14.77 (19.84)
ICU	6,928 (14.52)
Hospital Type	
Investor-owned, under 100 beds	351 (.74)
Investor-owned, 100 or more beds	7,789 (16.32)
Not-for-profit, rural, under 100 beds	233 (.49)
Not-for-profit, rural, 100 or more beds	551 (1.15)
Not-for-profit, urban, under 100 beds	435 (.91)
Not-for-profit, urban, 100-299 beds	9,446 (19.84)
Not-for-profit, urban, 300 or more beds	28,898 (60.55)

Hospital IONM Utilization Thirtile Characteristics

Table 1.2 displays the characteristics for the top and bottom thirtiles of hospital IONM utilization. The bottom and top thirtiles showed a symmetric amount of spinal surgery across DRGs 460 and 473. In the top thirtile, 7,304 (58.6%) of procedures were DRG 460, followed by 4,386 (36.5%) in DRG 473. In the bottom thirtile, 11,143 (59.1%) of procedures were in DRG 460, followed by 7,050 (37.4%) in 473. These differences were statistically significant.

The prevalence of less complex and lower risk spinal procedures varied across the top and bottom thirtile. Specifically, in the top thirtile, 306 (2.5%) of procedures were in DRG 459, followed by 279 (2.3%) in DRG 471. In the bottom thirtile, 390 (2.1%) of procedures were in DRG 459, followed by 278 (1.5%) in DRG 417. The racial / ethnic characteristics were significantly different across the bottom and top thirtiles; Hispanics were more frequent utilizers of bottom thirtile hospitals. Patient sex was equally distributed across the thirtiles.

Significant differences in payer source across the IONM thirtiles was observed. Specifically, the top IONM thirtile consisted of 5,515 (45.9%) privately insured patients and 3,967 (33.1%) of Medicare patients; the bottom thirtile was 7,641 (40.5%) privately insured patients and 7,719 (40.9%) Medicare patients. There were also differences in the IONM thirtiles related to patient socioeconomic status. In the top IONM thirtile, 3,703 (31.4%) of patients were in the highest quartile of household income and only 1,884 (16.0%) of patients were in the lowest quartile of household income. In the bottom IONM thirtile, fewer patients were in the higher income quartile and a greater proportion of patients were in the lower quartile of household income. This difference was statistically significant. Patients in the top IONM thirtile had a higher median number of chronic conditions (median 4.0) when compared to the lower IONM thirtile (median=3.0).

Discharge patterns significantly varied according to IONM thirtile. In the top thirtile, 16,412 (87.0%) of patients were discharged to their homes. In the bottom thirtile, 10,347 (86.2%) were discharged to their homes. The top and bottom thirtiles also varied geographically, as 46.4% of top IONM thirtile patients were located in New York, followed by 25.7% in Florida. Sixty percent of bottom IONM thirtile patients were in Florida and 22.6% were located in New York.

Table 1.2.

Hospital Characteristics of Top and Bottom Thirtiles of IONM Utilization.

	Bottom 1/3 of IONM Utilizers N=18,861	**Top 1/3 of IONM Utilizers N=12,005**	***p***
	N(%) or Mean (sd)	**N(%) or Mean(sd)**	
MS-DRG Code			
459	390 (2.1)	306 (2.5)	<.001
460	11,143 (59.1)	7,034 (58.6)	
471	278 (1.5)	279 (2.3)	
473	7,050 (37.4)	4,386 (36.5)	
Patient Level Factors			
Race / Ethnicity			
White	14,959 (80.0)	9,908 (83.3)	<.001
Black	1,276 (6.8)	699 (5.9)	
Hispanic	1,304 (7.0)	469 (3.9)	
Asian or Pacific Islander	166 (.9)	141 (1.2)	
Native American	48 (.3)	35 (.3)	
Other	952 (5.1)	637 (5.4)	
Sex			
Male	8814 (46.7)	5617 (46.8)	.925
Female	10047 (53.3)	6388 (53.2)	
Age (Mean;sd; *t*)	58.07 (13.95)	56.39 (13.87)	<.001
Median(Range)	59.00 (4-95)	57.00 (0-95)	<.001
Payer Source			
Medicare	7,719 (40.9)	3,967 (33.1)	<.001
Medicaid	769 (4.1)	651 (5.4)	
Private insurance	7,641 (40.5)	5,515 (45.9)	
Self-pay	286 (1.5)	165 (1.4)	
No charge	46 (.2)	29 (.2)	
Other	2,400 (12.7)	1,676 (14.0)	
Socioeconomic Status (Median Household Income Quartiles)			
First quartile	4,205 (22.7)	1,884 (16.0)	<.001
Second quartile	5,377 (29.0)	2,893 (24.6)	
Third quartile	5,214 (28.1)	3,297 (28.0)	
Fourth quartile	3,728 (20.1)	3,703 (31.4)	

Charlson Score (Median, Range)	.00 (0-9)	.00 (0-9)	<.001
Number of chronic conditions	3.00 (0-18)	4.00 (0-18)	<.001
Discharge			
Home	16,412 (87.0)	10,347 (86.2)	<.001
SNF	832 (4.4)	715 (6.0)	
Other	1,617 (8.6)	943 (7.9)	
Hospital Factors			
Location			
Florida	11,339 (60.1)	3,091 (25.7)	<.001
Massachusetts	1,039 (5.5)	1,222 (10.2)	
New York	4,269 (22.6)	5,572 (46.4)	
Washington	2,214 (11.7)	2,120 (17.7)	

Hypothesis 1: Length of Stay

Hypothesis 1 examined whether hospitals with a high rate (> 67th percentile) of IONM use for low risk spinal surgeries will have lower length of stay (LoS) rates than hospitals with low use (< 33rd percentile) of IONM. The estimated mean hospital LoS was calculated using a generalized log-linked multivariable regression model adjusting for patient- and hospital-level confounders.

Findings from hypothesis 1 suggest that the top thirtile of IONM utilizing hospitals across DRGs 460 and 473 had mean LoS of 2.58 days (95% CI 2.55-2.61) (Table 1.3). In comparison, the bottom thirtile of IONM utilizing hospitals had a mean LoS of 2.54 days (95% CI 2.52-2.56). This yielded a difference of 0.04 days in LoS between the two thirtiles, however 95% the confidence interval of these two means overlap suggesting the difference is not significant.

Table 1.3.

Mean* Hospital Length of Stay Comparisons between of Top and Bottom IONM and Non-IONM Surgery Thirtiles.

	Length of Stay for IONM Procedures (DRGs 460 and 473)	95% CI	**Length of Stay for Non-IONM Procedures** (All DRGs)	95% CI
Top 1/3 of utilizers	2.58	2.55-2.61	2.71	2.67-2.74
Bottom 1/3 of utilizers	2.54	2.52-2.56	2.68	2.66-2.70

***** Estimated using log-link general liner models adjusting LOS estimates for any effect of imbalance in patient and hospital characteristics for the groups

Hypothesis 2: IONM Thirtiles and 30DRR

Hypothesis 2 posited that hospitals with a high rate (> 67th percentile) of IONM use for low risk spinal surgeries will have lower 30-day readmission rates than hospitals with low use (< 33rd percentile) of IONM. Table 1.4 displays the results from the multivariate regression conducted testing the association between the top and bottom thirtiles of hospital IONM utilizers for lower risk, less complex spinal procedures (DRGs 460 and 473). This model was adjusted for both patient and hospital level confounders to include: race, sex, age, Charlson score, payer source, median patient household income, and state. Results suggested that higher IONM utilizing hospitals were associated with 14.9% lower odds (OR = .851, 95% CI = .83-.99; *p*-value .001) of 30DRR.

Predictors of Re-admission

30DRR and Race. For the lower risk, less complex spinal procedures, African Americans displayed 33.8% greater odds (OR 1.338, 95% CI 1.20-1.63; *p*-value .001) of being readmitted within 30-days when compared to Caucasian patients.

30DRR and Age/Charlson Score. For the lower risk, less complex spinal procedures, as a patient's age and Charlson score increase, odds of re-admission increased by 1.7% (OR 1.017, 95% CI 1.01-1.02; *p*-value <.001) and 27% (OR 1.270, 95% CI 1.23-1.34; *p*-value <.001).

30DRR and Payer Source. For the lower risk, less complex spinal procedures, private insurance patients had a 43% lower odds (OR .564, 95% CI .49-.61; *p*-value <.001) of readmission when compared to Medicare beneficiaries. Self-pay patients displayed 67% lower odds of readmission (OR .334, 95% CI .22-.59; *p*-value <.001) when compared to Medicare beneficiaries.

30DRR and Household Income. Patients in the second quartile of income had significantly lower odds of incurring a readmission within 30-days when compared to patients in the lowest (e.g., first) income quartile (OR .887, 95% CI .79-.99; *p*-value .047). There was no difference in the odds of readmission between the highest two quartiles and the lowest income quartile.

30DRR and Geographical Location. When compared to Florida, Washington patients had 18.2% (OR .818, 95% CI .74-.96, *p*-value = .005) lower odds of being readmitted within 30-days. There was a marginally significant difference in the odds of readmission between Massachusetts and Florida (OR .848, 95% CI .65-.92, *p*-value 0.076). No significant difference in readmission between patients in Florida and New York was detected.

Table 1.4.

Logistic Regression Comparison of 30-day Readmission Rates of Lower Risk, Less Complex Spinal Surgeries against All Four Spinal DRGs.

	30-Day Readmission **Lower Risk, Less Complex Spine Surgeries** (DRGs 460 and 473)	
	Odds Ratio (95% CI)	***p***
IOM Percentile		
Top 1/3 of utilizers	.851 (.833-.991)	.001
Bottom 1/3 of utilizers	Referent	
Patient Level Factors		
Race / Ethnicity		
White	Referent	
Black	1.338 (1.196-1.626)	.001
Hispanic	.993 (.829-1.181)	.941
Asian or Pacific Islander	.792 (.580-1.358)	.334
Native American	.863 (.365-1.991)	.753
Other	1.206 (1.047-1.485)	.047
Sex		
Male	Referent	
Female	.985 (.877-1.025)	.723
Age	1.017 (1.013-1.021)	<.001
Charlson Score	1.270 (1.229-1.344)	<.001
Payer Source		
Medicare	Referent	
Medicaid	.879 (.709-1.086)	.268
Private insurance	.564 (.492-.614)	<.001
Self-pay	.334 (.216-.585)	<.001
No charge	.582 (.385-1.867)	.298
Other	.682 (.581-.788)	<.001
Median Household Income Quartiles		
First quartile	Referent	
Second quartile	.887 (.791-.990)	.047
Third quartile	.949 (.836-1.047)	.390

Fourth quartile	.939 (.844-1.078)	.344
Hospital Location		
Florida	Referent	
Massachusetts	.848 (.651-.923)	.076
New York	1.087 (.948-1.168)	.136
Washington	.818 (.739-.959)	.005

Hypothesis 3: IONM Thirtile and LoS

Hypothesis 3 compared LoS across the top IONM utilizing hospitals with the top thirtile of surgical volume of all other hospitals in the sample. Specifically, hypothesis 3 tested whether hospitals with a high rate (>67th percentile) of IONM use for low risk spine surgery would have lower LoS when compared to a subgroup of hospitals above the 50th percentile of hospitals in state by surgical volume of the DRGs of interest. The goal driving this hypothesis was to identify whether organizational practice patterns displaying high volume use of IONM have any meaningful difference in hospital outcomes to organizations who are of similar surgical volume but do not use IONM during their spine surgeries. Stratified analyses were conducted using only the sub-group of hospitals ranked in the top 50th percentile by number of annual surgeries performed. Results are presented in Table 1.5.

High volume hospitals. In high volume hospitals, the mean LoS the top thirtile of IONM use was 3.06 days (95% CI 3.04-3.09). Among hospitals in the bottom thirtile of IONM use, mean LoS was 2.76 days (95% CI 2.74-2.78).

All Hospitals**.** The top thirtile of IONM utilizers yielded an estimated mean LoS of 2.58 days (95% CI 2.55-2.61). The bottom thirtile of hospitals displayed an estimated mean LoS of 2.54 days (95% CI 2.52-2.56).

Comparison of the estimated mean LoS in the top thirtile of IONM utilizing hospitals (3.06 days) with the top thirtile of all hospitals conducting spine surgery (2.58 days) in this sample, LoS for all hospitals was .48 days less than the high volume subgroup.

Table 1.5

All Study Hospitals and the Sub-group of Hospitals Ranked in the top 50th Percentile by Number of Annual Surgeries Performed: Comparing Estimated Mean* LoS for the Hospitals as Defined by IONM Use

	Length of Stay Mean (95% CI)
All Hospital Utilizers (DRGs 460 and 473)	
Top 1/3 of IONM utilizers	2.58 (2.55-2.61)
Bottom 1/3 of IONM utilizers	2.54 (2.52-2.56)
Subgroup of Hospitals with High Volume of Surgeries (> 50th percentile in number of surgeries)	
Top 50th percentile of Spine Surgery	3.06 (3.04-3.09)
Bottom 50th percentile of Spine Surgery	2.76 (2.74-2.78)

Hypothesis 4: 30DRR for Top IONM Thirtile vs Spine Surgery Sub-group Greater Than 50th Percentile

Hypothesis 4 compared only high volume hospitals, determined as a subgroup of hospitals in the greater than 50th percentile for spine surgery volume.

Specifically, hypothesis 4 examined whether hospitals in these high volume groups with a high IONM use rate (>67th) during low risk spine surgery had a lower 30-day readmission rate than a subgroup of hospitals above the 50th percentile of hospitals in state by surgical volume of the DRGs of interest. The high volume (>50th percentile), all hospital subgroup comparison captured all procedures and did not control for DRG, case complexity, or lower risk surgeries. Stratified analyses were conducted using only the sub-group of hospitals ranked in the top 50th percentile by number of annual surgeries performed. The Odds Ratio for the greater than 50th percentile, all hospital subgroup was .917 (.852-.988), *p*-value 0.23.

Table 1.6

All Study Hospitals and the Sub-group of Hospitals Ranked in the top 50th Percentile by Number of Annual Surgeries Performed: Comparing 30DRR for the Hospitals as Defined by IONM Use

	30-Day Re-Admission Odds Ratio (95% CI)	***p***
Subgroup of Hospitals with High Volume of Surgeries (> 50th percentile in number of surgeries)		
Top percentile	.917 (.852-.988)	.023
Bottom percentile	Referent	
IONM Utilizing Hospitals (DRGs 460 and 473)		
Top Thirtile	.851 (.833-.991)	.001
Bottom Thirtile	Referent	

CHAPTER V
DISCUSSION

Introduction

This chapter will compile the study's summary extrapolated from the data analysis presented in Chapter IV. Chapter V will also provide a discussion across the spectrum of implications for action and recommendations for further research.

Study Summary

There is a significant body of literature supporting IONM as a clinically useful surgical adjunct in preventing iatrogenic injury to patients during complex spinal surgery (Fehlings et al., 2010; Lall et al., 2012; Sala et al., 2007) However, routine use of IONM on less complex procedures is regularly called into question by both clinicians, administrators, and payers. One of the primary reasons IONM remains in debate on less complex spinal procedures is the lack of robust data supporting IONM's ability to reduce the already small number of surgical complications, thus reducing patient length of stay (LoS) and 30-day re-admission rate (30DRR), and in the end increasing value and decreasing costs of spine surgery.

Reducing LoS and 30DRR is to the benefit for all, including patients, physicians, and insurance companies (Boozary, Manchin, & Wicker, 2015). The purpose of this study was to describe the relationship between various hospital utilization rates of IONM and their respective hospital outcomes for LoS and 30DRR. This ultimately will assist all stakeholders to better understand the real value of IONM on less complex spinal procedures.

This study used 2012 archival inpatient data from hospitals located in Florida, Massachusetts, New York, and Washington. The analysis examined the spectrum of spine surgeries across four DRGs: 459, 460, 471, and 473. These DRGs were analyzed with the hospital as the unit of analysis, and organized by IONM utilization by top and bottom thirtiles, using the 00.94 ICD-9CM code for IONM. Statistical techniques, including multivariable logistic regression and the log-link generalized linear model, were used to analyze the relationship between IONM utilization thirtile and hospital LoS and 30-day readmissions.

The major findings of this study suggested that higher utilization of IONM on less complex and lower risk spinal procedures (DRGs 460 and 473) reduced 30-day readmission by 14.9% (Table 1.7, OR .851) for hospitals in the top thirtile of IONM use, when compared to the bottom hospital thirtile of IONM use. The results for hospital IONM utilization and LoS require further analysis as LoS did not significantly change across the top and bottom thirtiles of IONM utilizers.

Additionally, the results for the 30DRR for the all hospital subgroup (>50th percentile of surgery) (.917, CI .852-.988) further supports hypothesis 1 by showing the differences in odds ratios were not related to the annual volume of surgeries across the groups. This comparison truly reinforces the results of 14.9% 30DRR reduction for high IONM utilizing hospitals.

Table 1.7

Comparing 30DRR from Hospital Top and Bottom IONM Thirtiles and All Study Hospitals

	30DRR for Only Low Risk Surgeries – IONM (DRG 460 and 473)		**30DRR for Sub-group Hospitals above the 50th Percentile State Ranking by Spine Surgery Volume**	***p***
Top Utilizers Odds Ratio (95% CI)	**.851 (.833-.991)**	**.001**	**.917 (.852-.988)**	**.023**
Bottom Utilizers Odds Ratio (95% CI)	Referent		Reference	

Table 1.8

Comparing LoS from Hospital Top and Bottom IONM Thirtiles and All Study Hospitals

	LoS for Only Low Risk Surgeries – IONM (DRG 460 and 473)		**LoS for Sub-group Hospitals above the 50th Percentile State Ranking by Spine Surgery Volume**	
Top Utilizers Estimated Mean (95% CI)	**2.58 (2.55-2.61)**		**3.06 (3.04-3.09)**	
Bottom Utilizers Estimated Mean (95% CI)	**2.54 (2.52-2.56)**		**2.76 (2.74-2.78)**	

Findings and Current Literature

The body of literature supporting the use of IONM on less complex and less risky spinal procedures needs further development and assessment, and this study illuminates a number of areas for future research on this topic. In addition to the limited literature supporting IONM's use on less complex procedures, no available studies to date have looked at various hospital IONM utilization levels and their respective influence on LoS and 30DRR. This study's approach in analyzing the relationship between hospital IONM utilization and LoS and 30DRR would expand our knowledge of whether hospitals with higher volumes of IONM utilization produce better outcomes than lower IONM utilizing hospitals. This concept of higher volume practice of procedures being strongly correlated with better outcomes is a widely-studied concept across various medical specialties (Bederman et al., 2009; Brevig et al., 2015; Mehrotra & Dimick, 2015).

Ney et al. (2015) were the most recently published, foundational articles supporting IONM's positive utility, at the level of the patient, for less complex and lower risk spinal procedures. Ney et al. (2015) used data compiled by AHRQ's Nationwide Inpatient Sample (NIS). Their findings yielded:

1. Using IONM on these spinal procedures was associated with less neurological complications, 0.8% vs 1.4% of controls (Ney et al., 2015);
2. IONM as a cost effective surgical adjunct, based on the costs of performing IONM compared to the risk of patient injury during spinal surgery and the lifetime costs for patients with spinal cord injury (Ney et al., 2013).

This study picks up the conversation where Ney et al (2015) and Ney et al. (2013) left off, and looks at IONM utilization from the context of not only benefiting the patient intraoperatively but also benefiting hospital and patient after surgery. This study's implications may help the various stakeholders involved in patient care to further understand IONM's value proposition.

30-day readmissions rates remain a huge target for quality improvement efforts for anyone working in healthcare. Readmission expenses are costing U.S. hospitals over $4.3 billion dollars annually across all surgeries (Barrett, Wier, Jiang, & Steiner, 2014; Hines, Barrett, Jiang, & Steiner, 2014). While spine surgery continues to show considerable increase in utilization, its costs and readmissions continue to be a significant opportunity for improvement. Spinal disease, specifically spondylosis, intervertebral disk disorders and generalized back problems ranks 10 out of 17 of the most expensive conditions to treat for Medicare patients. Driving a significant portion of these costs is the fact that spinal laminectomies, disc excisions, and spinal fusions are in the top five of most frequently readmitted patient populations across all surgeries (Weiss, Elixhauser, & Steiner, 2013)

Application of Study Results

Applying the 30DRR results from this study could provide significant cost savings to hospitals and third party insurance payers for patients across DRGs 460 and 473. Hospitals utilizing IONM in high volume may be provided a significant opportunity to lower their 30-day readmissions for one of their most expensive surgical service lines.

Hypothetical Cost Savings Model. Using this study's results in a hypothetical scenario affords a better understanding for hospital administrators and physician leaders. From this study's sample, the following calculations displayed:

1. Mean Medicare Cost per Discharge from this Sample = $24,150.
2. Number of Medicare Patients Readmitted from this Sample = 2,629
3. Mean Medicare Cost Per Readmission from this Sample = $12,729
4. Total Cost of 30-day Readmissions for All Medicare Patients = $12,729 x 2629 patients = $33,464,541
5. IONM Adj. 30-day Total Readmissions Costs (14.9% reduction) = $12,729 x 2,238 = $28,487,502
6. Total IONM Costs = 2,629 patients x $750 industry average hospital fee = $1,971,750

This information above allows the calculation of total cost savings for high utilizing IONM hospitals:

(Total Cost of 30-day readmissions) – (IONM Adjusted 30-day Readmission Costs) – (Costs of IONM) = $33,464,541 – $28,487,502 – $1,971,750= $3,005,298 In Savings ($1,143 per procedure).

This model above takes several assumptions: based on averaged cost data, did not weigh DRG 460 or 473 separately, does not account for insurance payments to IONM providers, does not account for patient quality of life after discharge, and finally it assumes an industry standard fee of $750 per IOM procedure billed to the hospital.

Hypothetical HRRP Cost Savings Model. The Hospital Readmissions Reduction Program (HRRP) was established via the Affordable Care Act (ACA). This program allows CMS to penalize hospital Medicare reimbursements for having higher readmissions, compared to the national average, for: heart failure, acute myocardial infarction, chronic obstructive pulmonary disease (COPD), elective hip or knee replacement, and coronary artery bypass graft (CABG) and pneumonia. If a hospital fails to perform better than the national average on readmissions for any of these procedures, CMS can penalize the hospital's reimbursement for all Medicare procedures, not just those listed above.

To apply these potential penalties to a hypothetical cost model, the following assumptions were made:

1. Assuming a hospital with 300 spinal procedures (Medicare) Total Costs = (300 x $24,150.87) = $7,245,261
2. Assuming the national HRRP Penalty of 0.67%, Readmission Penalities for this cohort = ($7,245,261 x .67%) = $48,543
3. Assuming a proposed HRRP Penalty of 1.0%, Readmission Penalities for this cohort = ($7,245,261 x 1.0%) $72,452
4. Assuming a proposed HRRP Penalty of 3.0%, Readmission Penalities for this cohort = $7,245,261 x 3.0%) $217,357

To summarize, in addition to the $3.0 million potential savings in readmission costs, hospitals with higher IONM utilization for lower risk, less complex procedures may have further opportunity to maximize revenue and reduce penalities by avoiding HRRP penalities, ranging anywhere from $48k-$217k annually.

Recognizing the simplicity of these models above, this model could be further refined with additional analyses such as including the other fiscal benefits to hospitals reducing their 30-day readmission rates. These could include hospitals increasing patient satisfaction scores and market share, and also improving bed and staff utilization ratios.

Depending on the particular hospital and their payer contracts, hospitals who have more pay-for-performance and at-risk payment agreements could benefit significantly from reducing their 30-day readmission rates within their spinal surgery DRGs. Lastly, spine pathology causes more global disability than any other condition, and as the patient age demographics continue to shift to older generations, value added and cost effective treatment of these disorders will become paramount (Hoy et al., 2014).

Study Strengths

This study offers several strengths not previously explored when looking at hospital IONM utilization and its relationship to hospital performance metrics. Utilizing data AHRQ's HCUP SID affords this study a large sample size across four different states in different regions of the United States across an entire calendar year. To date, there have been no studies analyzing IONM with the hospital as the unit of analysis, nor any studies looking at various hospital utilization levels and the influence on 30DRR and LoS.

Study Limitations

There are a number of limitations to this study. The analysis and results are solely dependent upon the quality of documenting and coding embodied inside both the hospital discharge records and the HCUP SID. The documentation quality inside these databases directly impact the reporting of this study's results. Any flaws in the collection, documentation, and reporting from the HCUP SID could cause under or over-reporting of IONM utilization, readmissions, or days a patient was hospitalized. A specific example for this study was the authors intended to include more states in the analysis, however the initial eight states had to be reduced down to four states, due to the quality of data across the available database. Specifically, the elimination of four of the eight initial states was due to lack of adequate readmission data. As discussed in the literature review, there is considerable discussion and concern surrounding the accuracy of documenting spinal surgery complication rates through retrospective data analysis (Nasser et al., 2010; Wang et al., 2012), for this reason we compare hospital outcomes for high and low utilizers of IONM.

Another limitation of the HCUP SID database is its use of ICD-9CM codes, instead of Current Procedure Terminology (CPT) codes. CPT codes would allow for a more granular analysis of the specific clinical modalities used by the IONM services providers throughout the entire sample.

Next, IONM's practice on the national level is widely unstandardized, and when combining this high degree of unstandardized practice with less specific clinical data, the authors cannot ascertain if the actual IONM services were conducted to acceptable industry standards. This could confound IONM's effectiveness in influencing the primary variables of interest, 30DRR and LoS.

The variables and procedures analyzed in this study rely upon multiple medical professionals and their inherent skills, including: the surgeon, the interpreting IONM physician, and the technical IONM professional. All three of these professionals can influence critical patient care variables of LoS and 30DRR.

Recommendations for Future Studies

Retrospective analysis is becoming more popular with increase of large, archival claim databases such as the HCUP NIS, HCUP SID, Truven MarketScan, Humana

Pearl Driver, and several more. However, research surrounding IONM would be better served from a dedicated, longitudinally based, prospectively administrated database and/or registry. Ideally, these prospective datasets would maximize patient and hospital demographics, especially patient and procedural clinical information. Documenting IONM modalities, protocols, and patient outcomes would allow for a significant strengthening of the IONM body of literature. Several IONM professional societies and large national IONM have initiated their own respective IONM registries, and with additional time and increased sample size there will be opportunities for further value added research on IONM.

In addition to prospective, quantitative based analyses, IONM would also benefit from qualitative analyses. Very little research exists capturing data behind customers choosing or not choosing IONM, physician and hospital alike. The body of research exploring physician perceptions of the various modalities and techniques of IONM remains underdeveloped. To date, no qualitative research exists analyzing insurance carrier’s perceptions of IONM and respective reimbursement rates. The field of IONM would greatly benefit from a broader base of research exploring the various utilizer positions driving the market.

CHAPTER VI
CONCLUSION

Patient discharge records from four HCUP SID databases across FL, NY, MA, and WA, from DRGs 459, 460, 471, and 473, were analyzed to explore any association with IONM utilization and hospital outcomes of 30DRR and LoS. Specifically, the data was analyzed using SAS and SPSS to compare 30DRR and LoS across the top and bottom thirtiles of IONM utilizing hospitals and across the subgroup of state hospitals above the 50th percentile in surgical volume. This study heightens the much needed awareness to the value behind IONM's use on lower risk, less complex spinal surgery.

Higher IONM utilizing hospitals have significant potential to reduce their 30DRR by 14.9% across DRGs 460 and 473, when compared to lower utilizing hospitals. This reduction in 30DRR could generate a cascade of benefits to hospitals and their patients ranging from cost savings, to increased patient satisfaction, and more favorable reimbursement contracts. LoS in both the top and bottom hospital IONM thirtiles did not show any significant difference, and the relationship between IONM and LoS would benefit from further analysis.

Reducing preventable 30-day readmissions continues to be in the forefront of policies surrounding quality improvement and medical reimbursement initiatives across all clinical and surgical populations. This study provides meaningful discussion in support of using IONM on less complex spinal procedures through its 14.9% reduction in 30-day readmissions.

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